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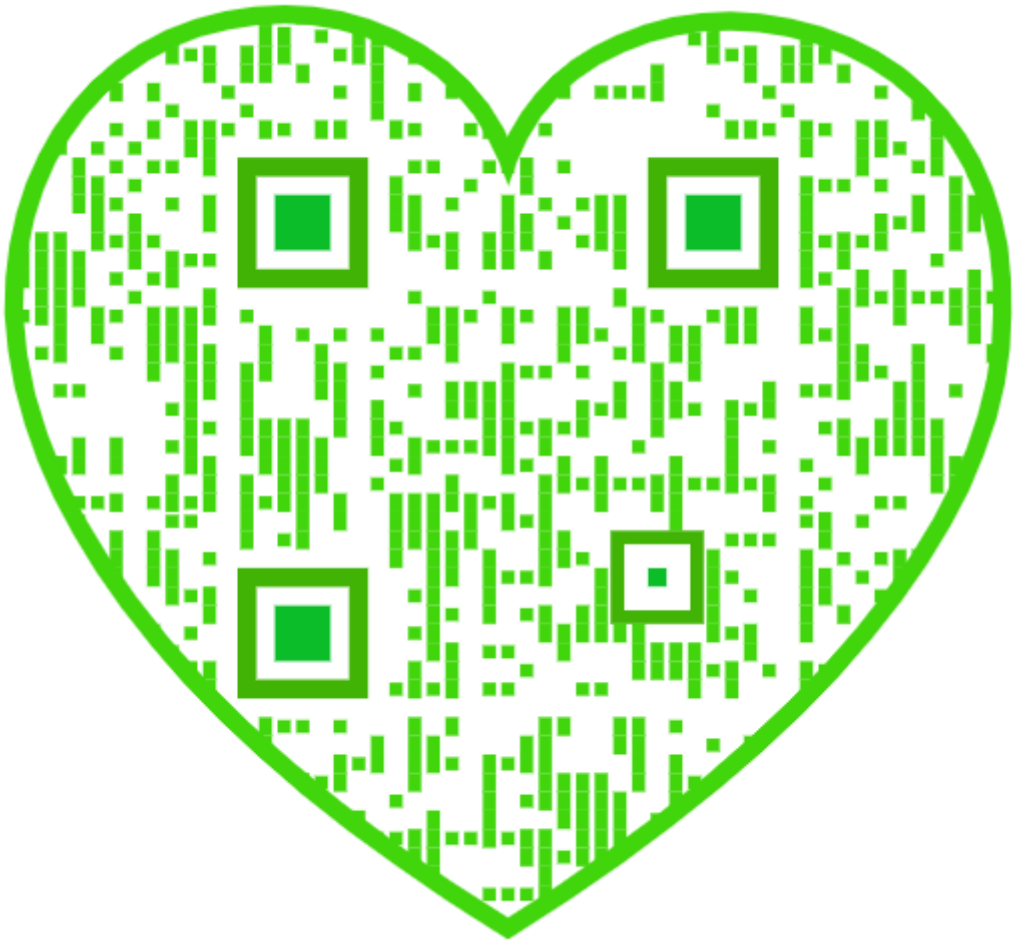
A COURSE

IN

STRUCTURAL DRAFTING



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A COURSE

IN

STRUCTURAL DRAFTING

A description of material used in structural design and drafting room practice relating to same with a few plates for the student.

Compiled and Arranged

BY

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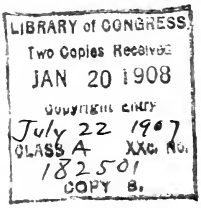

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W. D. BROWNING

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PREFACE

The compilation of the matter for this book has taken some time, but the writer wishes to extend to the students of the country the first collection of this kind intended for their use.

He wishes to thank Mr. J. D MOONEY for the aid in collection of matter and in executing the drawings in such practical form.

W. D. BROWNING.

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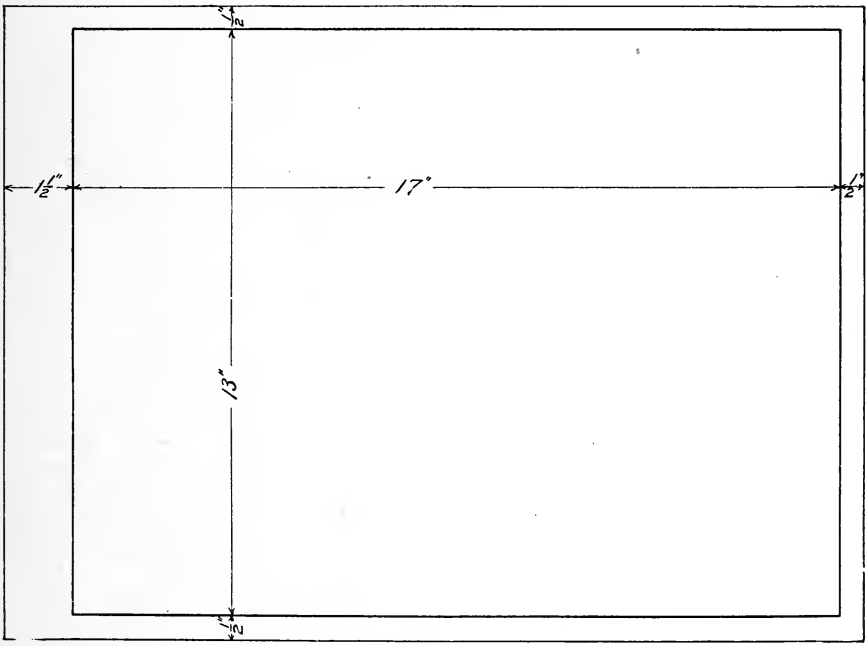
INTRODUCTION

The demand for draftsmen and designers who are acquainted with the materials and practices used in large structures of iron and steel has led a few schools to shape a course of instruction along this line but no book has appeared giving matter that will enable the student to obtain a simple knowledge of these things. The object of the writer is to present to the student some information that will enable him to understand the standards and practices in structural drafting.

The matter here given has been compiled from the hand books issued by Carnegie Steel Co., The Am. Bridge Co., from articles in *The Draftsman* and other periodicals and from examples that have come under the observation of the writer.

This course is laid out to conform to one in Mechanical Drawing by Mr. F. H. Sibley and the writer and the sheets are to be 14 x 19 when finished. The outline of borders are shown in the folowing illustration:



Outline of Plates

Suggestions and data are given for quite a number of plates and by drawing a title plate as shown in the last chapter the student will have a nice cover for a booklet of his work.

The titles on the sheets are to be placed in the lower right hand corner and arranged as follows:

PLATE VII
Course 1 Structural Drawing
Central Institute
Name Date

STRUCTURAL DRAWING.

CHAPTER I.

By Structural Drawing we mean such work that will enable the student to make and understand the drawings used in the construction of structures of iron and steel.

All are familiar with the high steel frame work Fig. 1 used as the skeleton of our modern high office buildings and will no doubt understand that these frames are made of special shaped pieces.

Since the manufacturers of these pieces of material have made them of certain shapes for a number of years it has become a universal practice to put them in according to these standards. The shape of the pieces being denoted by the name given to their cross section or other characteristics.

For instance an eye-bar is one, either square or round, having a hole or eye formed at the end to receive a pin or bolt.

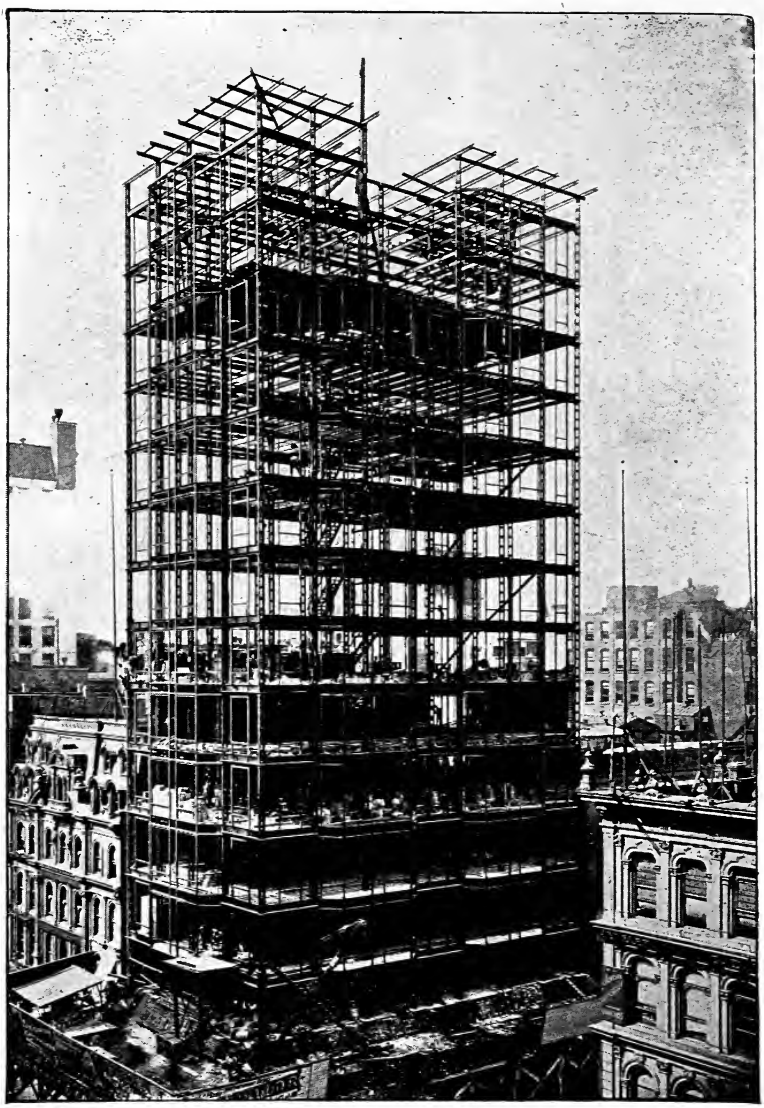
The simplest shape for structural material is a sheet of iron or steel called a "plate," varying in thickness from say $\frac{1}{16}$" to 2" and in sizes up to 58" x 160".

The process of making these sheets is the repeated rolling of a mass of highly heated metal, and this also applies to other shapes, too, though in the latter cases the faces of the rolls are grooved to the form desired. To make a heavier piece the rolls are separated slightly and the section of the piece thus enlarged. The most common forms are the I-beams, the channel, the angle and the railroad rail, then a modification of the I-beam will give the deck-beam, of the angle will give the Z-bar and the rail will give a Tee. Fig. 2.

The illustrations show the shape of the cross sections of each of the above styles with names of the parts. Structural shapes are denoted by *size* and weight and this is considered at a certain amount per foot; there being only a few sizes in some of the lists. The I-beam, generally, has several weights to a size, that is, the size is the distance noted in the illustration as "depth."

I-beams and channels are denoted by size (depth) and weight per foot, the angles, Z-bars and T-bars by length of legs and thickness, the rails by weight *per yard,* only.

Tables have been compiled by the manufacturers of structural shapes that contain much valuable matter. A condensed tables are given on pages 6, 7, 8,



Reliance Building, during Construction.
Aug. 1, 1894.

Fig. 1

Structural Frame for an Office Building

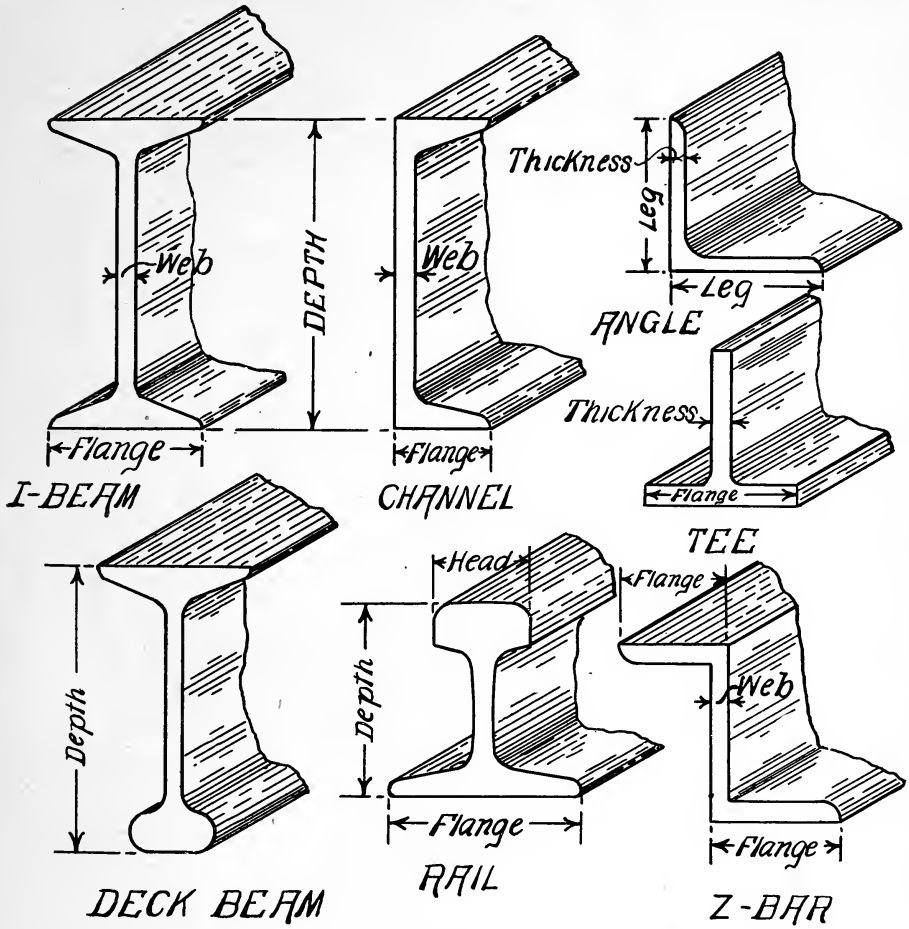


Fig. 2

Field Work—Structural parts are laid out, cut and riveted in the shop but are put together at the place of erection. This erecting work is said to be done in the "field" and often constitutes the largest amount of the labor.

Riveting that is to be done in the shop is designated in one way while that for the field is shown another on thedrawings. This will be discussed in chapter on *Riveting.*

SLOPE AND FILLETS OF FLANGES.

It will be seen that the inside of the flanges of I-beams and channels increase in thickness and this slope has been adopted as 2″ per foot while the slope on the rail base is 13°, by the Carnegie Co. The fillet is the curve in corners of the structural shapes.

The small fillets on Carnegie I-beams and channels have been made to a radius of 6-10 of the minimum web thickness;

the large fillets to a radius of the minimum web thickness plus 1-10 of an inch.

Draftsmen often cut out their triangles as shown in Fig. 4 to aid in drawing these shapes, the manner of laying off the slopes is as follows:

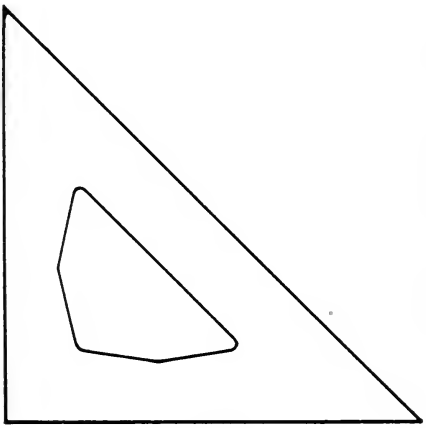


Fig. 4

Make a lay out as in Fig. 5 with the line at slant of 2″ in 12″ or 1″ in 6″, and cut the triangle so to fit the line.

Reverse the triangle and finish both slopes at I and for those at *R* use a slant line at 13° with the horizontal and cut the triangle to fit. Scratch *I* for I-beam and *R* for rail.

COPING.

When one beam or channel is to fit into another and be connected by an angle the end of the intruding beam is cut to conform to the other and this process is called "Coping." Fig. 6.

The slopes on the "coped" ends are practically that of the section of the other beam. When one beam is deeper than the other only one side is coped of the entering beam and often the former is connected at such a position that no coping is necessary. Coping is done on a special machine in the more modern shops.

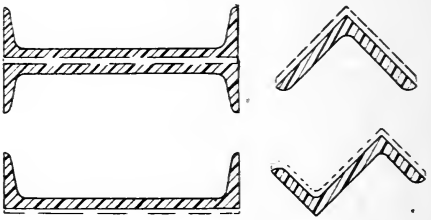


Fig. 3.

This illustration shows the manner of increasing the weight of different shapes and it should be noted that only certain parts are effected, thus when the rolls are separated the web of I-beams and channel only are affected while in the angle and Z-bar the web and legs both are increased.

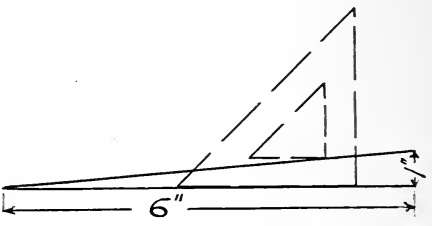


Fig. 5

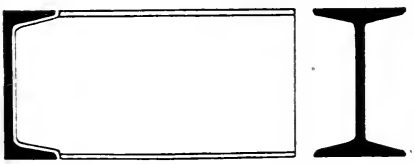


Fig. 6.

DRAWING SECTIONS.

When the section of a structural shape is to be shown it is customary to arrange and blacken as in Fig. 8, but when larger and time will permit, it may be sectioned as in Fig. 7.

If the section is blackened the rivet holes are drawn open as shown in Fig. 9, but where the end view of a shape is to be drawn the rivet holes are put in black, Fig. 10.

This will apply also to side views of shapes as in Fig. 11.

When a side view of a shape shows the edge of a flange two lines are used to represent this, as in Fig. 11, but in case a channel is shown with the back toward the draftsman, dotted lines will be used for the flanges.

The holes in the back flange on the side view should be shown as at *a*, Fig. 11, with center line and "hatching" across it and those on the front flange are blackened as in the web.

Thus, the workman will understand that the holes shown this way, are open and are to be filled by rivets, or bolts, in the "field."

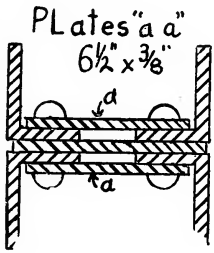


Fig. 7

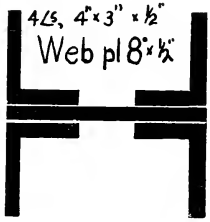


Fig. 8

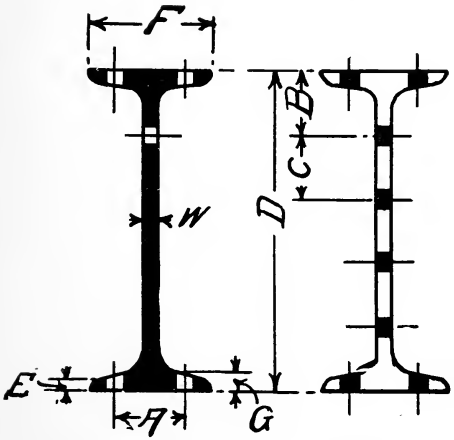


Fig. 9

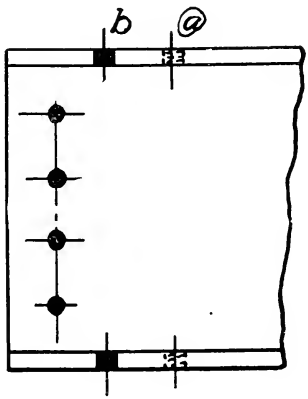
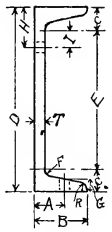


Fig. 10

Fig. 11

PROPORTIONS OF CHANNELS

(**Carnegie**)



E is the max distance that could be used for a splice plate and H should be taken so that I is not less than $1\frac{1}{2}$ times the diameter of the rivet.

R = $\frac{6}{10}$ of the min. Web thickness (T)

For 24″ it would be .6×$\frac{1}{2}$″=.3″

F = Min. Web (T)+$\frac{1}{15}$″ and on 24″ would be $\frac{1}{2}+\frac{1}{10}=\frac{6}{10}$″

Slope of flange is 2″ in 1 ft.

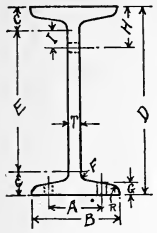
Those marked **s** are stock sizes which are easily obtained, the others are special but can be secured if desired.

In ordering, designate wt. or thickness wanted but not both.

In calculating the areas and wts. of the various sections here shown, the fillets are disregarded.

Depth D	Wt. per Foot in Lbs.	Width Flange B	Thickness T	A	C	E	G	Max Rivet	Area
15	55.00	3 13/16	13/16	$2\frac{1}{4}$	$1\frac{3}{8}$	$12\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	16.18
	50.00	3 23/32	23/32	"	"	"	"	"	14.71
	45.00	3 5/8	5/8	"	"	"	"	"	13.24
	40.00	3 17/32	17/32	$1\frac{5}{8}$	"	"	$2\frac{1}{32}$	"	11.76
	35.00	3 27/64	27/64	"	"	"	"	"	10.29
s	33.00	3 13/32	13/32	"	"	"	"	"	9.90
12	40.00	3 27/64	49/64	2	1	10	$1\frac{5}{32}$	$\frac{3}{4}$	11.76
	35.00	3 19/64	41/64	"	"	"	"	"	10.29
	30.00	3 11/64	33/64	"	"	"	"	"	8.82
	25.00	3 3/64	25/64	$1\frac{5}{4}$	"	"	"	"	7.35
s	20.50	2 15/16	9/32	"	"	"	"	"	6.03
10	35.00	3 3/16	53/64	2	$\frac{7}{8}$	$8\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	10.29
	30.00	3 1/32	43/64	"	"	"	"	"	8.82
	25.00	2 57/64	17/32	"	"	"	"	"	7.35
	20.00	2 47/64	3/8	$1\frac{1}{2}$	"	"	$\frac{7}{16}$	"	5.88
s	15.00	2 19/32	15/64	"	"	"	"	"	4.46
9	25.00	2 13/16	39/64	$1\frac{3}{4}$	$\frac{7}{8}$	$7\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	7.35
	20.00	2 21/32	29/64	"	"	"	"	"	5.88
	15.00	2 31/64	9/32	$1\frac{3}{8}$	"	"	$\frac{13}{32}$	"	4.41
s	13.25	2 7/16	15/64	"	"	"	"	"	3.89
8	21.25	2 5/8	37/64	$1\frac{1}{2}$	$\frac{7}{8}$	$6\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	6.25
	18.75	2 17/32	31/64	"	"	"	"	"	5.51
	16.25	2 7/16	25/64	"	"	"	"	"	4.78
	13.75	2 11/32	19/64	$1\frac{1}{4}$	"	"	"	"	4.04
s	11.25	2 17/64	7/32	"	"	"	"	"	3.35
7	19.75	2 33/64	5/8	$1\frac{1}{2}$	$\frac{3}{4}$	$5\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{8}$	5.81
	17.25	2 13/32	33/64	"	"	"	"	"	5.07
	14.75	2 19/64	13/32	$1\frac{1}{4}$	"	"	$\frac{11}{32}$	"	4.34
	12.25	2 13/64	5/16	"	"	"	"	"	3.60
s	9.75	2 3/32	13/64	"	"	"	"	"	2.85
6	15.50	2 9/32	9/16	$1\frac{3}{8}$	$\frac{3}{4}$	$4\frac{1}{2}$	$\frac{11}{32}$	$\frac{5}{8}$	4.56
	13.00	2 5/32	7/16	"	"	"	"	"	3.82
	10.50	2 1/32	5/16	$1\frac{1}{8}$	"	"	"	"	3.09
s	8.00	1 59/64	13/64	"	"	"	"	"	2.38
5	15.50	2 1/32	15/32	$1\frac{1}{4}$	$\frac{5}{8}$	$3\frac{3}{4}$	$\frac{5}{16}$	$\frac{1}{2}$	3.38
	9.00	1 57/64	21/64	"	"	"	"	"	2.65
s	6.50	1 3/4	3/16	1	"	"	"	"	1.95
4	7.25	1 23/32	21/64	1	$\frac{5}{8}$	$2\frac{3}{4}$	$\frac{9}{32}$	$\frac{1}{2}$	2.13
	6.25	1 21/32	17/64	"	"	"	"	"	1.84
s	5.25	1 37/64	3/16	"	"	"	"	"	1.55
3	6.00	1 39/64	3/8	$1\frac{5}{16}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{8}$	1.76
	5.00	1 1/2	17/64	"	"	"	"	"	1.47
s	4.00	1 13/32	11/64	"	"	"	"	"	1.19

PROPORTIONS OF I-BEAMS (Carnegie)



Depth D	Wt. per Ft.	B	T	A	C	E	G	Max. Rivet	Area
24″	100	$7\frac{1}{4}$	$\frac{3}{4}$	4	$1\frac{5}{8}$	$20\frac{3}{4}$	$\frac{27}{32}$	$\frac{7}{8}$	29.41
	95	$7\frac{3}{16}$	$\frac{11}{16}$	″	″	″	″	″	27.94
	90	$7\frac{1}{8}$	$\frac{5}{8}$	″	″	″	″	″	26.47
	85	$7\frac{1}{16}$	$\frac{9}{16}$	″	″	″	″	″	25.00
s	80	7	$\frac{1}{2}$	″	″	″	″	″	23.32
20″	100 0	$7\frac{9}{32}$	$\frac{7}{8}$	4	$1\frac{3}{4}$	$16\frac{1}{2}$	$\frac{29}{32}$	$\frac{7}{8}$	29.41
	95	$7\frac{13}{64}$	$\frac{51}{64}$	″	″	″	″	″	27.94
	90	$7\frac{9}{64}$	$\frac{47}{64}$	″	″	″	″	″	26.47
	85	$7\frac{1}{16}$	$\frac{21}{32}$	″	″	″	″	″	25.00
s	80	7	$\frac{19}{32}$	″	″	″	″	″	23.73
	75	$6\frac{13}{32}$	$\frac{23}{32}$	$3\frac{1}{3}$	$1\frac{1}{8}$	17	$\frac{25}{32}$	″	22.06
	70	$6\frac{21}{64}$	$\frac{37}{64}$	″	″	″	″	″	20.59
s	65	$6\frac{1}{4}$	$\frac{1}{2}$	″	″	″	″	″	19.08
18″	70	$6\frac{17}{64}$	$\frac{23}{32}$	$3\frac{1}{4}$	$1\frac{3}{8}$	$15\frac{1}{4}$	$1\frac{1}{16}$	$\frac{7}{8}$	20.59
	65	$6\frac{1}{64}$	$\frac{21}{32}$	″	″	″	″	″	19.12
	60	$6\frac{3}{32}$	$\frac{5}{8}$	″	″	″	″	″	17.65
s	55	6	$\frac{37}{64}$	″	″	″	″	″	15.93
15	100	$6\frac{25}{64}$	$1\frac{3}{16}$	$3\frac{3}{4}$	2	11	$1\frac{1}{32}$	$\frac{7}{8}$	29.41
	95	$6\frac{13}{64}$	$1\frac{5}{64}$	″	″	″	″	″	27.94
	90	$6\frac{3}{64}$	$\frac{63}{64}$	″	″	″	″	″	26.47
	85	$6\frac{51}{64}$	$\frac{57}{64}$	″	″	″	″	″	25.00
s	80	$6\frac{1}{32}$	$\frac{13}{16}$	″	″	″	″		23.81
								$\frac{3}{4}$	
15	75	$6\frac{9}{64}$	$\frac{57}{64}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$11\frac{3}{4}$	$1\frac{3}{16}$	″	22.06
	70	$6\frac{3}{16}$	$\frac{25}{32}$	″	″	″	″	″	20.59
	65	$6\frac{3}{32}$	$\frac{11}{16}$	″	″	″	″	″	19.12
s	60	6	$\frac{19}{32}$	″	″	″	″	″	17.67
15	55	$5\frac{3}{4}$	$\frac{21}{32}$	3	$1\frac{1}{4}$	$12\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	16.18
	50	$5\frac{5}{8}$	$\frac{5}{8}$	″	″	″	″	″	14.71
	45	$5\frac{35}{64}$	$\frac{29}{64}$	″	″	″	″	″	13.24
s	42	$5\frac{1}{2}$	$\frac{19}{32}$	″	″	″	″	″	12.48
12	55	$5\frac{39}{64}$	$\frac{13}{16}$	3	$1\frac{3}{8}$	$9\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	16.18
	50	$5\frac{31}{64}$	$\frac{11}{16}$	″	″	″	″	″	14.71
	45	$5\frac{25}{64}$	$\frac{9}{16}$	″	″	″	″	″	13.24
s	40	$5\frac{1}{4}$	$\frac{29}{64}$	″	″	″	″	″	11.84
	35	$5\frac{9}{32}$	$\frac{7}{16}$	$2\frac{3}{4}$	$1\frac{1}{8}$	$9\frac{3}{4}$	$1\frac{7}{32}$	″	10.29
s	31 5	5	$\frac{11}{32}$						9.26
10	40	$5\frac{3}{32}$	$\frac{3}{4}$	$2\frac{5}{8}$	1	8	$1\frac{5}{32}$	$\frac{3}{4}$	11.76
	35	$4\frac{61}{64}$	$\frac{39}{64}$	″	″	″	″	″	10.29
	30	$4\frac{13}{16}$	$\frac{15}{32}$	″	″	″	″	″	8.82
s	25	$4\frac{21}{32}$	$\frac{5}{16}$	″	″	″	″	″	7.37
9	35	$4\frac{49}{64}$	$\frac{47}{64}$	$2\frac{1}{2}$	1	7	$1\frac{7}{16}$	$\frac{3}{4}$	10.29
	30	$4\frac{39}{64}$	$\frac{37}{64}$	″	″	″	″	″	8.82
	25	$4\frac{29}{64}$	$\frac{27}{64}$	″	″	″	″	″	7.35
s	21	$4\frac{21}{64}$	$\frac{13}{64}$	″	″	″	″	″	6.31
8	25 5	$4\frac{17}{64}$	$\frac{17}{32}$	$2\frac{1}{4}$	$\frac{7}{8}$	$6\frac{1}{4}$	$1\frac{3}{32}$	$\frac{3}{4}$	7.50
	23 0	$4\frac{11}{64}$	$\frac{7}{16}$	″	″	″	″	″	6.76
	20 5	$4\frac{3}{32}$	$\frac{23}{64}$	″	″	″	″	″	6.03
s	18 0	4	$\frac{17}{64}$	″	″	″	″	″	5.33

E is the max distance that could be used for a splice plate and H should be taken so that I is not less than $1\frac{1}{2}$ times the diameter of rivet.

R = $\frac{6}{10}$ of the min. Web thickness (T)

For 24″ it would be .6×$\frac{1}{2}$″=.3″

F = Min. Web (T)+$\frac{1}{10}$″ and on 24″ would be $\frac{1}{2}+\frac{1}{10}=\frac{6}{10}$″

Slope of flange is 2″ in 1 ft.

PROPORTIONS OF I-BEAMS—(*Continued*)

Those marked S are stock sizes which are easily obtained, the others are special but can be secured if desired.

In ordering, designate weight or thickness wanted, but not both

In calculating the areas and weights of the various sections here shown, the fillets are disregarded.

Depth D	Wt. per Ft.	B	T	A	C	E	G	Max. Rivet	Area
7	20.0	$3\frac{7}{8}$	$\frac{15}{32}$	$2\frac{1}{4}$	$\frac{7}{8}$	$5\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	5.88
	17.5	$3\frac{49}{64}$	$\frac{29}{64}$	"	"	"	"	"	5.15
S	15.0	$3\frac{21}{64}$	$\frac{1}{4}$	"	"	"	"	"	4.42
6	17.25	$3\frac{37}{64}$	$\frac{31}{64}$	2	$\frac{3}{4}$	$4\frac{1}{2}$	$\frac{11}{32}$	$\frac{5}{8}$	5.07
	14.75	$3\frac{29}{64}$	$\frac{23}{64}$	"	"	"	"	"	4.34
S	12.25	$3\frac{21}{64}$	$\frac{15}{64}$	"	"	"	"	"	3.61
5	14.75	$3\frac{19}{64}$	$\frac{1}{2}$	$1\frac{3}{4}$	$\frac{3}{4}$	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{2}$	4.34
	12.25	$3\frac{9}{64}$	$\frac{11}{32}$	"	"	"	"	"	3.60
S	9.75	3	$\frac{13}{64}$	"	"	"	"	"	2.87
4	10.5	$2\frac{7}{8}$	$\frac{13}{32}$	$1\frac{1}{2}$	$\frac{5}{8}$	$2\frac{3}{4}$	$\frac{9}{32}$	$\frac{1}{2}$	3.09
	9.5	$2\frac{13}{16}$	$\frac{11}{32}$	"	"	"	"	"	2.79
	8.5	$2\frac{47}{64}$	$\frac{17}{64}$	"	"	"	"	"	2.50
S	7.5	$2\frac{21}{64}$	$\frac{3}{16}$	"	"	"	"	"	2.21
3	7.5	$2\frac{33}{64}$	$\frac{23}{64}$	$1\frac{7}{16}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{8}$	2.21
	6.5	$2\frac{27}{64}$	$\frac{17}{64}$	"	"	"	"	"	1.91
S	5.5	$2\frac{21}{64}$	$\frac{11}{64}$	"	"	"	"	"	1.63

CHAPTER II.

RIVETS AND SPACING

All structural work is held together by rivets or bolts, the former nearly always put in hot. When the work is to be riveted together in the shop the heads of the rivet are shown full on the drawing, but the body need not be dotted. If it is to be riveted in the "field" the draftsman draws a circle the size of the hole and fills it black, Fig. 11. Convenient signs have been adopted to show the manner of riveting desired whether full heads or countersunk head is here given, Fig. 12.

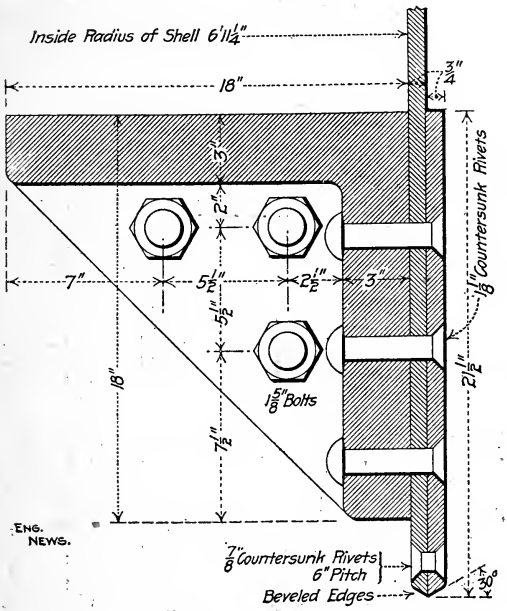


Fig. 12

A side view of the full head should be shown as a half circle, Fig. 7.

There are several forms of rivet heads among which are the flat, the cone, the button, the steeple and the countersunk. Countersinking of the rivet is carried out to several degrees, depending much on what the conditions in which the work is to be finished.

The word "countersunk" means simply the tapering of the hole outward and forcing the hot rivet to fill it and the excess of material remaining rough. When a smooth surface is required this excess must be cut off, and the term, "countersunk and chipped," arises.

Several "degrees" of finish is noted in the standards adopted for the use of designers by concerns making or using structural steel but nearly every drafting room has its own list.

Fig. 13 gives some sizes of rivets and it will be noted that the angle of the countersunk head is generally drawn 60°.

The Conventional Rivet Signs are made up from the books of the Am. Bridge Co., and Carnegie Stel Co., and presents the average practice. Fig. 14.

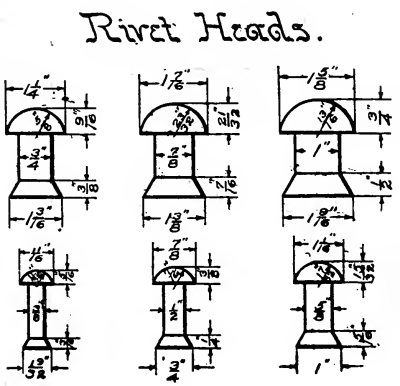
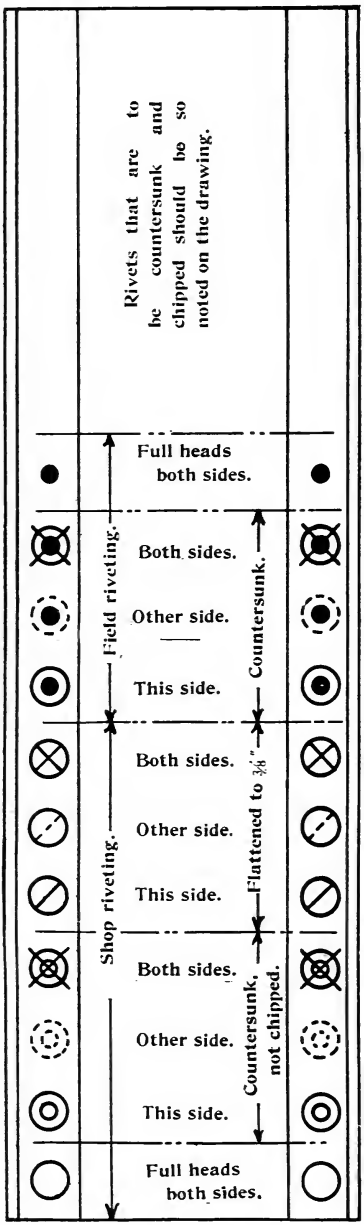


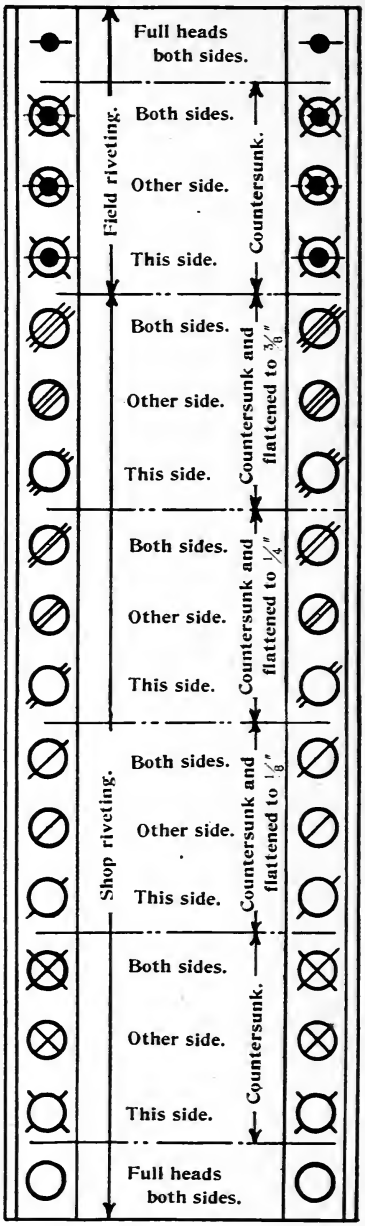
Fig. 13

CONVENTIONAL RIVET SIGNS.

American Bridge Co. Standard.



Carnegie Standard.



Vertical and horizontal center lines should run through rivets.

Fig. 14

Most of the riveting in the shop is done with a machine and much of the "field" rivets are driven by the same method, too.

Machine driven rivets have usually the same form for both heads, but occasionally a cone or even the pointed head are found.

The proportions Fig. 15 shown are based on the diameter of the body, that is, 1.75 would mean 1.75 x d.

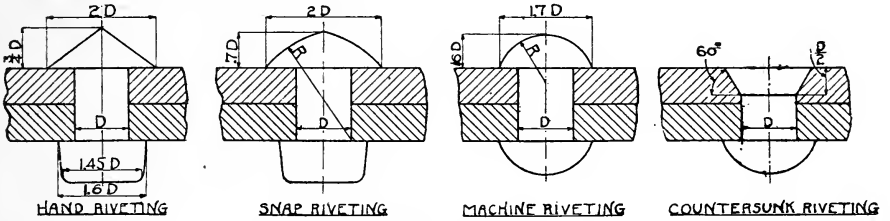


Fig. 15

Rivet holes are always punched $\frac{1}{32}$ to $\frac{1}{16}$" larger than the rivet to be used and the squeezing of the hot rivet fills up the space.

With careful men to lay out and punch the work the parts go together without much difficulty but to bring two holes in line which are slightly off center, a *drift* pin may be needed which is hammered or wedged into the holes to draw the metal enough to permit a rivet to be inserted, Fig. 16, but the rivet never fills the hole perfectly.

In riveting up work a heater prepares the rivet to proper heat then gives it to a helper who puts it in place where it is held by the riveter for an instance while the helper places a "dolly" bar against its head.

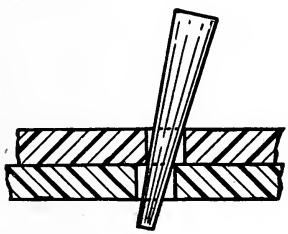


Fig. 16

The riveter then forms the other head but care must be exercised in finishing that he not strike it to cold for fear that the head will fly off.

When the rivet is to be extended the $\frac{1}{8}$ or $\frac{1}{4}$ or $\frac{3}{8}$ as indicated by the signs the depth of the hole for countersinking need not be so much in the latter as in the former case.

Of course there is a wide difference between the theoretical and actual conditions in riveting.

A theoretically perfect rivet should fill the hole completely, be of homogeneous material throughout and have two well formed heads.

In Fig. 17 are shown some of the more frequent imperfections in rivet

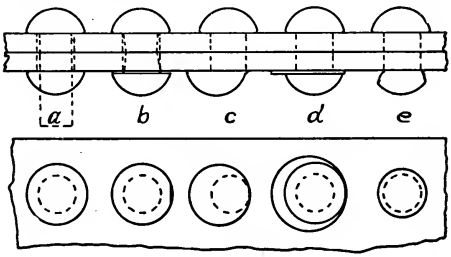


Fig. 17

work resulting from carelessness of the workmen.

At *a* for comparison, is shown a perfectly driven rivet, the original form being shown dotted, this "shank" being $\frac{1}{32}$ to $\frac{1}{16}$ of an inch less in diameter than the hole which it is to fill and enough longer to make a perfect head.

The amount of metal held by the rivet is called the "grip," it may be the two plates, a plate and angle, two angles or any other structural shape.

Both heads should be concentric with the body and the rivet should be perfectly tight, the failure to be so is more

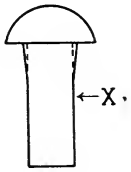


Fig. 18

apt to be the result of machine than hand riveting, since the former has a fixed distance to move in closing up the rivet.

If the rivet gives a clear, sharp ring when struck with a light hammer, it may be considered tight.

At *b* is shown a loose rivet which has been "caulked" with a cold-chisel to make it appear tight—a common trick.

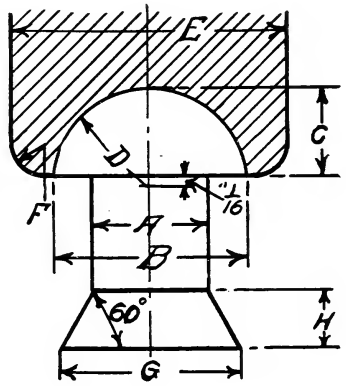
A close inspection should be made of the heads for signs of the caulking tool, especially if the rivet has been generously besmeared with fresh paint or tobacco juice.

Form *c* is probably due to uneven heating one side mashing down allowing the head to be formed off the center.

The condition shown at *d* results from two much metal in the shank of the rivet before driving, giving a "soldier cap" head. The reverse of this is shown at *e*, (not enough metal). In the case of *c* and *d* the full strength of the rivet is probably developed and may be allowed to pass if that is all that is desired but *b* and *e* should be condemned unquestioningly. If the rivet could be secured like in Fig. 18 it would aid quite materially in the shop if uniformly heated.

It would insure the complete filling of the hole up to the head. Many firms have designed rivet dies for their machines and the sizes of a well known firm is shown in Fig. 19.

Shop rivets are generally calculated at higher values than field-driven rivets, it being assumed that they are driven by machine riveters capable of exerting a heavy pressure.



Standard Rivets and Dies.

A	B	C	D	E	F	G	H
3/8	11/16	9/32	11/32	1	1/8	5/8	3/16
1/2	7/8	3/8	7/16	1 1/4	5/32	13/16	1/4
5/8	1 1/16	15/32	17/32	1 1/2	11/64	1	5/16
3/4	1 1/4	9/16	5/8	1 3/4	13/64	1 3/16	3/8
7/8	1 7/16	21/32	23/32	2	7/32	1 3/8	7/16
1	1 5/8	3/4	13/16	2 1/4	1/4	1 9/16	1/2
1 1/4	2	15/16	1	3	5/16	1 15/16	5/8

Fig. 19

It is important, therefore, to avoid placing them in positions that cannot be reached by the machine riviter. Rivets that can not be reached by the machine must be driven by hand at a much greater cost.

SPACING.

The distance between the center of rivets in the same line is called the "pitch" and the arrangement is termed "spacing."

The lettering and figuring may be shown as in Fig. 20, where several

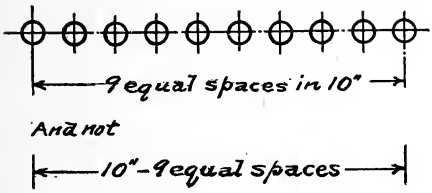


Fig. 20

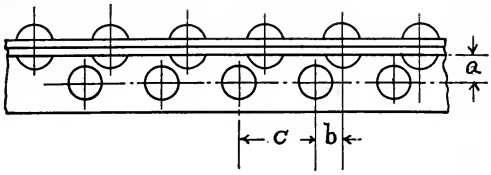
spaces are the same, this being better than to dimension the whole in small and irregular fractions of an inch.

The distance from the back of an angle to the center of a rivet hole is called the "gage."

The "gage" of rivet holes in the flanges of I-beams is from center to center of holes, in fact the term may be applied as meaning "center to center" of holes or from a "face" to the center.

Some data on minimum spacing is here given, Fig. 21.

The minimum distance from the center of any rivet hole to a sheared edge ought not be less than 1½ inches for ⅞-inch rivets, 1¼ inches for ¾-inch rivets, 1⅛ inches for ⅝-inch rivets and



MINIMUM RIVET SPACING.

SIZE of RIVET	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
MINIMUM DIST. FOR C	1	$1\frac{1}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{5}{8}$	3

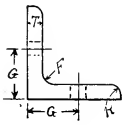
WHEN A IS	FOR RIVET DIAMETER OF $\frac{3}{4}$" b INCHES	FOR RIVET DIAMETER OF $\frac{7}{8}$" b INCHES
$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{5}{16}$
$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$
$1\frac{5}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$
$1\frac{3}{8}$	$\frac{15}{16}$	$1\frac{1}{8}$
$1\frac{7}{16}$	$\frac{7}{8}$	1
$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{15}{16}$
$1\frac{9}{16}$	$\frac{5}{8}$	$\frac{13}{16}$
$1\frac{5}{8}$	$\frac{3}{8}$	$\frac{11}{16}$
$1\frac{11}{16}$	O	$\frac{1}{2}$
$1\frac{3}{4}$	O	$\frac{5}{16}$

Fig. 21

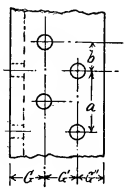
1 inch for ½-inch rivets, and to the rolled edge, 1¼, 1⅛, 1 and ⅞ inches, respectively; the maximum distance from any edge should be eight times the thickness of the plate.

SPACING IN ANGLES

From Hand Book of Carnegie, Cambria, American Bridge Co. and others.



The fillet (F) and the round (R) are for the smaller size, the thickening process increasing T but not the curves.



The rivet holes on 8″ and 6″ angles may be opposite each, but on 5″ staggered.

On 8″=G=3″
G′=3½″
G″=1½″
On 6″=G=2½″
or 2¼
G′=2″or 2½
G″=1½″

On 6″, G is some times taken as 2½″ G′ as 2¼″ and G″ as 1¼

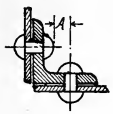
The distance, centre to centre of rivets, should not be less than 3d or more than 16d, so *a* would be at least 4d.

It is best not to space rivets rivets on same line in the two leg when not staggered.

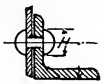
Size	T	F	R	G	Wt. per foot	Area sq. in.	Max Rivet (d)
8 x 8	1 1/8	5/8	5/16	4	56.9	16.73	7/8 or 1
"	1 1/16	"	"	"	54.0	15.87	"
"	1	"	"	"	51.0	15.00	"
"	15/16	"	"	"	48.1	14.12	"
"	7/8	"	"	"	45.0	13.23	"
"	13/16	"	"	"	42.0	12.34	"
"	3/4	"	"	"	38.9	11.44	"
"	11/16	"	"	"	35.8	10.53	"
"	5/8	"	"	"	32.7	9.61	"
"	9/16	"	"	"	29.6	8.68	"
"	1/2	"	"	"	26.4	7.75	"
6 x 6	1	1/2	3/8	3 1/2	37.4	11.00	7/8 or 1
"	15/16	"	"	"	35.3	10.37	"
"	7/8	"	"	"	33.1	9.74	"
"	13/16	"	"	"	31.0	9.09	"
"	3/4	"	"	"	28.7	8.44	"
"	11/16	"	"	"	26.5	7.78	"
"	5/8	"	"	"	24.2	7.11	"
"	9/16	"	"	"	21.9	6.43	"
"	1/2	"	"	"	19.6	5.75	"
"	7/16	"	"	"	17.2	5.06	"
"	3/8	"	"	"	14.9	4.36	"
5 x 5	1	1/2	3/8	2 3/4	30.6	9.00	7/8 or 1
"	15/16	"	"	"	28.9	8.50	"
"	7/8	"	"	"	27.2	7.99	"
"	13/16	"	"	"	25.4	7.46	"
"	3/4	"	"	"	23.6	6.94	"
"	11/16	"	"	"	21.8	6.42	"
"	5/8	"	"	"	20.0	5.58	"
"	9/16	"	"	"	18.1	5.31	"
"	1/2	"	"	"	16.2	4.75	"
"	7/16	"	"	"	14.3	4.18	"
"	3/8	"	"	"	12.3	3.61	"
4 x 4	13/16	3/8	5/16	2 1/4	19.9	5.84	7/8 or 1
"	3/4	"	"	"	18.5	5.44	"
"	11/16	"	"	"	17.1	5.03	"
"	5/8	"	"	"	15.7	4.61	"
"	9/16	"	"	"	14.3	4.18	"
"	1/2	"	"	"	12.8	3.75	"
"	7/16	"	"	"	11.3	3.31	"
"	3/8	"	"	"	9.8	2.86	"
"	5/16	"	"	"	8.2	2.40	"
3½ x 3½	13/16	5/16	1/4	2	17.1	5.03	7/8 or 1
"	3/4	"	"	"	16.0	4.69	"
"	11/16	"	"	"	14.8	4.34	"
"	5/8	"	"	"	13.6	3.98	"
"	9/16	"	"	"	12.4	3.62	"
"	1/2	"	"	"	11.1	3.25	"
"	7/16	"	"	"	9.8	2 87	"
"	3/8	"	"	"	8.5	2.48	"
"	5/16	"	"	"	7.2	2.09	"

SPACING IN ANGLES. (Continued)

The distance A should determine where rivets are to be staggered.

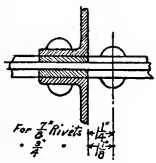


A = $\frac{1}{2}$ Diam. of head + $\frac{1}{4}$".



H is given as follows:—

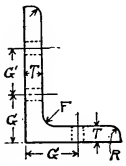
for $\frac{1}{2}$" rivet, $\frac{7}{8}$"
" $\frac{5}{8}$" " $1\frac{1}{16}$
" $\frac{3}{4}$" " $1\frac{1}{4}$
" $\frac{7}{8}$" " $1\frac{7}{16}$
" 1 " $1\frac{5}{8}$



Least amounts that can be used in spacing for rivets when machine driven.

Size	T	F	R	G	Wf. per foot	Area sq. in.	Max Rivet (d)
3 x 3	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{3}{4}$	11.5	3.36	$\frac{3}{4}$ or $\frac{7}{8}$
"	$\frac{9}{16}$	"	"	"	10.4	3.06	"
"	$\frac{1}{2}$	"	"	"	9.4	2.75	"
"	$\frac{7}{16}$	"	"	"	8.3	2.43	"
"	$\frac{3}{8}$	"	"	"	7.2	2.11	"
"	$\frac{5}{16}$	"	"	"	6.1	1.78	"
"	$\frac{1}{4}$	"	"	"	4.9	1.44	"
$2\frac{3}{4}$ x $2\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{2}$	8.5	2.50	$\frac{3}{4}$
"	$\frac{7}{16}$	"	"	"	7.6	2.22	"
"	$\frac{3}{8}$	"	"	"	6.6	1.92	"
"	$\frac{5}{16}$	"	"	"	5.6	1.62	"
"	$\frac{1}{4}$	"	"	"	4.5	1.31	"
$2\frac{1}{2}$ x $2\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$	$1\frac{3}{8}$	7.7	2.25	$\frac{3}{4}$
"	$\frac{7}{16}$	"	"	"	6.8	2.00	"
"	$\frac{3}{8}$	"	"	"	5.9	1.73	"
"	$\frac{5}{16}$	"	"	"	5.0	1.47	"
"	$\frac{1}{4}$	"	"	"	4.1	1.19	"
"	$\frac{3}{16}$	"	"	"	3.1	0.90	"
$2\frac{1}{4}$ x $2\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$	$1\frac{1}{8}$	6.8	2.00	$\frac{3}{4}$
"	$\frac{7}{16}$	"	"	"	6.1	1.78	"
"	$\frac{3}{8}$	"	"	"	5.3	1.55	"
"	$\frac{5}{16}$	"	"	"	4.5	1.31	"
"	$\frac{1}{4}$	"	"	"	3.7	1.06	"
"	$\frac{3}{16}$	"	"	"	2.8	0.81	"
2 x 2	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$1\frac{1}{8}$	5.3	1.56	$\frac{5}{8}$
"	$\frac{3}{8}$	"	"	"	4.7	1.36	"
"	$\frac{5}{16}$	"	"	"	4.0	1.15	"
"	$\frac{1}{4}$	"	"	"	3.2	0.94	"
"	$\frac{3}{16}$	"	"	"	2.5	0.72	"
$1\frac{3}{4}$ x $1\frac{3}{4}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$1\frac{5}{16}$	4.6	1.30	$\frac{5}{8}$
"	$\frac{3}{8}$	"	"	"	4.0	1.17	"
"	$\frac{5}{16}$	"	"	"	3.4	1.00	"
"	$\frac{1}{4}$	"	"	"	2.8	0.81	"
"	$\frac{3}{16}$	"	"	"	2.2	0.62	"
$1\frac{1}{2}$ x $1\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$1\frac{3}{16}$	3.4	0.99	$\frac{1}{2}$
"	$\frac{5}{16}$	"	"	"	2.9	0.84	"
"	$\frac{1}{4}$	"	"	"	2.4	0.69	"
"	$\frac{3}{16}$	"	"	"	1.8	0.53	"
"	$\frac{1}{4}$	"	"	"	1.3	0.36	"
$1\frac{1}{4}$ x $1\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$1\frac{1}{16}$	2.4	0.69	$\frac{1}{2}$
"	$\frac{1}{4}$	"	"	"	2.0	0.56	"
"	$\frac{3}{16}$	"	"	"	1.5	0.43	"
"	$\frac{1}{8}$	"	"	"	1.1	0.30	"
1 x 1	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{9}{16}$	1.5	0.44	$\frac{3}{8}$
"	$\frac{3}{16}$	"	"	"	1.2	0.34	"
"	$\frac{1}{8}$	"	"	"	0.8	0.24	"
$\frac{7}{8}$ x $\frac{7}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	1.0	0.29	$\frac{3}{8}$
"	$\frac{1}{8}$	"	"	"	0.7	0.21	"
$\frac{3}{4}$ x $\frac{3}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	0.9	0.25	$\frac{1}{4}$
"	$\frac{1}{8}$	"	"	"	0.6	0.17	"

SPACING IN ANGLES—Unequal Legs.



Those marked * are special, but can be obtained easily.

Size.	T	F	R	G	G1	Wt. per Foot	Area Sq. In.	Max. Rivet
* 8 x 3½	1 1/20	7/16	1/4	2	4	20.5	6.02	.....
* 7 x 3½	1	1/2	5/16	2	3½	32.3	9.50	7/8 or 1
"	15/16	"	"	"	"	30.5	8.97	"
"	7/8	"	"	"	"	28.7	8.42	"
"	13/16	"	"	"	"	26.8	7.87	"
"	3/4	"	"	"	"	24.9	7.31	"
"	11/16	"	"	"	"	23.0	6.75	"
"	5/8	"	"	"	"	21.0	6.17	"
"	9/16	"	"	"	"	19.1	5.59	"
"	1/2	"	"	"	"	17.0	5.00	"
"	7/16	"	"	"	"	15.0	4.40	"
6 x 4	1	1/2	3/8	2¼	3½	30.6	9.00	7/8 or 1
"	15/16	"	"	"	"	28.9	8.50	"
"	7/8	"	"	"	"	27.2	7.99	"
"	13/16	"	"	"	"	25.4	7.47	"
"	3/4	"	"	"	"	23.6	6.94	"
"	11/16	"	"	"	"	21.8	6.41	"
"	5/8	"	"	"	"	20.0	5.86	"
"	9/16	"	"	"	"	18.1	5.31	"
"	1/2	"	"	"	"	16.2	4.75	"
"	7/16	"	"	"	"	14.3	4.18	"
"	3/8	"	"	"	"	12.3	3.61	"
6 x 3¼	1	1/2	3/8	1¾	3½	28.9	8.50	7/8 or 1
"	15/16	"	"	"	"	27.3	8.03	"
"	7/8	"	"	"	"	25.7	7.55	"
"	13/16	"	"	"	"	24.0	7.06	"
"	1/2	"	"	"	"	22.4	6.56	"
"	11/16	"	"	"	"	20.6	6.06	"
"	5/8	"	"	"	"	18.9	5.55	"
"	9/16	"	"	"	"	17.1	5.03	"
"	1/2	"	"	"	"	15.3	4.50	"
"	7/16	"	"	"	"	13.5	3.97	"
"	3/8	"	"	"	"	11.7	3.42	"
5 x 4	7/8	7/16	5/16	2¼	2¾	24.2	7.11	7/8 or 1
"	13/16	"	"	"	"	22.7	6.65	"
"	3/4	"	"	"	"	21.1	6.19	"
"	11/16	"	"	"	"	19.5	5.72	"
"	5/8	"	"	"	"	17.8	5.23	"
"	9/16	"	"	"	"	16.2	4.75	"
"	1/2	"	"	"	"	14.5	4.25	"
"	7/16	"	"	"	"	12.8	3.75	"
"	3/8	"	"	"	"	11.0	3.23	"
5 x 3½	7/8	7/16	5/16	2	2¾	22.7	6.67	7/8 or 1
"	13/16	"	"	"	"	21.3	6.25	"
"	3/4	"	"	"	"	19.8	5.81	"
"	11/16	"	"	"	"	18.3	5.37	"
"	5/8	"	"	"	"	16.8	4.92	"
"	9/16	"	"	"	"	15.2	4.47	"
"	1/2	"	"	"	"	13.6	4.00	"
"	7/16	"	"	"	"	12.0	3.53	"
"	3/8	"	"	"	"	10.4	3.05	"
"	5/16	"	"	"	"	8.7	2.56	"

SPACING IN ANGLES—(Continued).

Those marked * are special, but can be obtained easily.

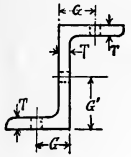
Size.	T	F	R	G	G1	Wt. per Foot	Area Sq. In	Max. Rivet
5 x 3	1 3/16	3/8	5/16	1 3/4	2 3/4	19.9	5.84	3/4 or 7/8
"	3/4	"	"	"	"	18.5	5.44	"
"	1 1/16	"	"	"	"	17.1	5.03	"
"	5/8	"	"	"	"	15.7	4.61	"
"	9/16	"	"	"	"	14.3	4.18	"
"	1/2	"	"	"	"	12.8	3.75	"
"	7/16	"	"	"	"	11.3	3.31	"
"	3/8	"	"	"	"	9.8	2.86	"
"	5/16	"	"	"	"	8.2	2.40	"
* 4 1/2 x 3	1 3/16	3/8	5/16	1 3/4	2 1/2	18.5	5.43	3/4
"	3/4	"	"	"	"	17.3	5.06	"
"	1 1/16	"	"	"	"	16.0	4.68	"
"	5/8	"	"	"	"	14.7	4.30	"
"	9/16	"	"	"	"	13.3	3.90	"
"	1/2	"	"	"	"	11.9	3.50	"
"	7/16	"	"	"	"	10.6	3.09	"
"	3/8	"	"	"	"	9.1	2.67	"
"	5/16	"	"	"	"	7.7	2.25	"
* 4 x 3 1/2	1 3/16	3/8	5/16	2	2 1/4	18.5	5.43	3/4
"	3/4	"	"	"	"	17.3	5.06	"
"	1 1/16	"	"	"	"	16.0	4.68	"
"	5/8	"	"	"	"	14.7	4.30	"
"	9/16	"	"	"	"	13.3	3.90	"
"	1/2	"	"	"	"	11.9	3.50	"
"	7/16	"	"	"	"	10.6	3.09	"
"	3/8	"	"	"	"	9.1	2.67	"
"	5/16	"	"	"	"	7.7	2.25	"
4 x 3	1 3/16	3/8	5/16	1 3/4	2 1/4	17.1	5.03	3/4
"	3/4	"	"	"	"	16.0	4.69	"
"	1 1/16	"	"	"	"	14.8	4.39	"
"	5/8	"	"	"	"	13.6	3.98	"
"	9/16	"	"	"	"	12.4	3.62	"
"	1/2	"	"	"	"	11.1	3.25	"
"	7/16	"	"	"	"	9.8	2.87	"
"	3/8	"	"	"	"	8.5	2.48	"
"	5/16	"	"	"	"	7.2	2.09	"
3 1/2 x 3	1 3/16	3/8	5/16	1 3/4	2	15.8	4.62	3/4
"	3/4	"	"	"	"	14.7	4.31	"
"	1 1/16	"	"	"	"	13.6	4.00	"
"	5/8	"	"	"	"	12.5	3.67	"
"	9/16	"	"	"	"	11.4	3.34	"
"	1/2	"	"	"	"	10.2	3.00	"
"	7/16	"	"	"	"	9.1	2.65	"
"	3/8	"	"	"	"	7.9	2.30	"
"	5/16	"	"	"	"	6.6	1.93	"
3 1/2 x 2 1/2	1 1/16	5/16	1/4	1 3/8	2	12.5	3.65	3/4
"	5/8	"	"	"	"	11.5	3.36	"
"	9/16	"	"	"	"	10.4	3.06	"
"	1/2	"	"	"	"	9.4	2.75	"
"	7/16	"	"	"	"	8.3	2.43	"
"	3/8	"	"	"	"	7.2	2.11	"
"	5/16	"	"	"	"	6.1	1.78	"
"	1/4	"	"	"	"	4.9	1.44	"

SPACING IN ANGLES—(Continued).

Those marked * are special, but can be obtained easily.

Size.	T	F	R	G	G1	Wt. per Foot.	Area Sq. In.	Max. Rivet.
* 3¼ x 2	9/16	5/16	¼	1⅛	1¾	9.0	2.64	¾
"	½	"	"	"	"	8.1	2.38	"
"	7/16	"	"	"	"	7.2	2.11	"
"	⅜	"	"	"	"	6.3	1.83	"
"	5/16	"	"	"	"	5.3	1.54	"
"	¼	"	"	"	"	4.3	1.25	"
3 x 2½	9/16	5/16	¼	1⅜	1¾	9.5	2.78	¾
"	½	"	"	"	"	8.5	2.50	"
"	7/16	"	"	"	"	7.6	2.22	"
"	⅜	"	"	"	"	6.6	1.92	"
"	5/16	"	"	"	"	5.6	1.62	"
"	¼	"	"	"	"	4.5	1.31	"
3 x 2	½	5/16	¼	1⅛	1¾	7.7	2.25	⅝
"	7/16	"	"	"	"	6.8	2.00	"
"	⅜	"	"	"	"	5.9	1 73	"
"	5/16	"	"	"	"	5.0	1.47	"
"	½	"	"	"	"	4.1	1.19	"
2½ x 2	½	¼	3/16	1⅛	1⅜	6.8	2.00	⅝
"	7/16	"	"	"	"	6.1	1.78	"
"	⅜	"	"	"	"	5.3	1.55	"
"	5/16	"	"	"	"	4.5	1.31	"
"	¼	"	"	"	"	3.7	1.06	"
"	3/16	"	"	"	"	2.8	0.81	"
* 2¼ x 1½	½	¼	3/16	1 1	1¼	5.6	1.63	⅝
"	7/16	"	"	"	"	5.0	1.45	"
"	⅜	"	"	"	"	4.4	1.27	"
"	5/16	"	"	"	"	3.7	1.07	"
"	¼	"	"	"	"	3.0	0.88	"
"	3/16	"	"	"	"	2.3	0.67	"
* 2 x 1⅜	¼	¼	3/16	⅝	1⅛	2.7	0.78	½
"	3/16	"	"	"	"	2.1	0.60	"
* 1⅜ x 1	¼	⅛	⅛	9/16	¾	1.9	0.53	½
"	⅛	"	"	"	"	1.0	0.28	"

Z BARS



Z Bars are known by depth of body or web and not by the legs.
For instance a 6″ Z-bar is given in the first nine rows at the top. The hole in the flanges are spaced as for angles and the one in the web could be ½ the height although the American Bridge Co. gives values as show for G′

The Fillet (F) is $\frac{5}{16}$″ and the round (R) $\frac{3}{16}$″ on all Z-Bars

Z-Bars marked special (*) are Listed in Carnegie Steel Co. book only, the other sizes from the same but very closely resembling the American Bridge Co.

The last size has one long flange with square corner inside and out.

Size	T	G	G′	Wt per foot	Area sq. in.	Max Rivet
$3\frac{1}{2} \times 6 \times 3\frac{1}{2}$	$\frac{3}{8}$	.....	3″	15.6	4.59	$\frac{7}{8}$
$3\frac{9}{16} \times 6\frac{1}{16} \times 3\frac{1}{16}$	$\frac{7}{16}$	.....	"	18.3	5.39	"
$3\frac{5}{8} \times 6\frac{1}{8} \times 3\frac{1}{8}$	$\frac{1}{2}$	.....	"	21.0	6.19	"
$3\frac{1}{2} \times 6 \times 3\frac{1}{2}$	$\frac{9}{16}$	.....	"	22.7	6.68	"
$3\frac{9}{16} \times 6\frac{1}{16} \times 3\frac{9}{16}$	$\frac{5}{8}$	.....	"	25.4	7.46	"
$3\frac{5}{8} \times 6\frac{1}{16} \times 3\frac{5}{8}$	$\frac{11}{16}$	.....	"	28.0	8.25	"
$3\frac{1}{2} \times 6 \times 3\frac{1}{2}$	$\frac{3}{4}$	.....	"	29.3	8.62	"
$3\frac{9}{16} \times 6\frac{1}{16} \times 3\frac{9}{16}$	$\frac{13}{16}$	.....	"	31.9	9.40	"
$3\frac{5}{8} \times 6\frac{1}{8} \times 3\frac{5}{8}$	$\frac{7}{8}$	.....	"	34.6	10.17	"
$3\frac{1}{4} \times 5 \times 3\frac{1}{4}$	$\frac{5}{16}$	.....	$2\frac{1}{2}$″	11.6	3.40	"
$3\frac{5}{16} \times 5\frac{1}{16} \times 3\frac{5}{16}$	$\frac{3}{8}$	.....	"	13.9	4.10	"
$3\frac{3}{8} \times 5\frac{1}{8} \times 3\frac{3}{8}$	$\frac{7}{16}$	.....	"	16.4	4.81	"
$3\frac{1}{4} \times 5 \times 3\frac{1}{4}$	$\frac{1}{2}$	.....	"	17.9	5.25	"
$3\frac{5}{16} \times 5\frac{1}{16} \times 3\frac{5}{16}$	$\frac{9}{16}$	.....	"	20.2	5.94	"
$3\frac{3}{8} \times 5\frac{1}{8} \times 3\frac{3}{8}$	$\frac{5}{8}$	.....	"	22.6	6.64	"
$3\frac{1}{4} \times 5 \times 3\frac{1}{4}$	$\frac{11}{16}$	.....	"	23.7	6.96	"
$3\frac{5}{16} \times 5\frac{1}{16} \times 3\frac{5}{16}$	$\frac{3}{4}$	.....	"	26.0	7.64	"
$3\frac{3}{8} \times 5\frac{1}{8} \times 3\frac{3}{8}$	$\frac{13}{16}$	.....	"	28.3	8.33	"
$3\frac{1}{16} \times 4 \times 3\frac{1}{16}$	$\frac{1}{4}$	.....	2″	8.2	2.41	$\frac{7}{8}$ or $\frac{3}{4}$
$3\frac{1}{8} \times 4\frac{1}{16} \times 3\frac{1}{8}$	$\frac{5}{16}$	....	"	10.3	3.03	"
$3\frac{3}{16} \times 4\frac{1}{8} \times 3\frac{1}{16}$	$\frac{3}{8}$	.....	"	12.4	3.66	"
$3\frac{1}{16} \times 4 \times 3\frac{1}{16}$	$\frac{7}{16}$	.....		13.8	4.05	"
$3\frac{1}{8} \times 4\frac{1}{16} \times 3\frac{1}{8}$	$\frac{1}{2}$	.....	"	15.8	4.66	"
$3\frac{3}{16} \times 4\frac{1}{8} \times 3\frac{3}{16}$	$\frac{9}{16}$	.....	"	17.9	5.27	"
$3\frac{1}{16} \times 4 \times 3\frac{1}{16}$	$\frac{5}{8}$	.....	"	18.9	5.55	"
$3\frac{1}{8} \times 4\frac{1}{16} \times 3\frac{1}{8}$	$\frac{11}{16}$	.....	"	20.9	6.14	"
$3\frac{3}{16} \times 4\frac{1}{8} \times 3\frac{3}{16}$	$\frac{3}{4}$	.....	"	23.0	6.75	"
$2\frac{11}{16} \times 3 \times 2\frac{11}{16}$	$\frac{1}{4}$	.....	1½	6.7	1.97	$\frac{3}{4}$
$2\frac{3}{4} \times 3\frac{1}{16} \times 2\frac{3}{4}$	$\frac{5}{16}$	.....	"	8.8	2.48	"
$2\frac{11}{16} \times 3 \times 2\frac{11}{16}$	$\frac{3}{8}$	.....	"	9.7	2.86	"
$2\frac{3}{4} \times 3\frac{1}{16} \times 2\frac{3}{4}$	$\frac{7}{16}$	.....	"	11.4	3.36	"
$2\frac{11}{16} \times 3 \times 2\frac{11}{16}$	$\frac{1}{2}$	.....	"	12.5	3.69	"
$2\frac{3}{4} \times 3\frac{1}{16} \times 2\frac{3}{4}$	$\frac{9}{16}$	.....	"	14.2	4.18	"
* 3 x 6 x 3	$\frac{3}{8}$	.....	3	14.5	.....	$\frac{7}{8}$
* $1\frac{1}{4} \times 1\frac{3}{4} \times 2\frac{1}{8}$	$\frac{7}{32}$	.....	None	3.5	.....	$\frac{1}{2}$

CHAPTER III.

BOLTS, EYEBARS AND PINS

The bolts used in structural work are nearly all square headed with square nuts and with ordinary V-threads of U. S. standard proportions.

To show a bolt on a drawing, approximate sizes are used, and the manner of drawing the head and nut are shown, in the Appendix.

Instead of drawing in all the lines for the plain V-thread several convenient methods have been used to represent them, as in No. 1, and No. 2, Fig. 21.

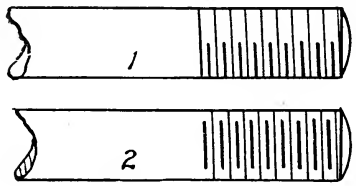


Fig. 22

The angle of the lines being about 86° or 87° with the horizontal. Threads may be either right or left hand, the latter never used in this work hence the lines should be shown sloped as in Fig. 22.

The rounding of the end of the bolt is made with a radius equal to two times the diameter of the bolt. The common length for the threads to be cut on bolts are shown in the following table. The number of threads per inch is the number of turns the nut must make to move it along the bolt a distance of 1".

The length of a bolt is the distance from the head to the end, it does not include the head.

In order that the strength of the threaded portion may be as strong as the body of the bolt the former is increased in size as shown in Fig. 23. This is called *upsetting* and the following table illustrate the amount allowed on round and square rods.

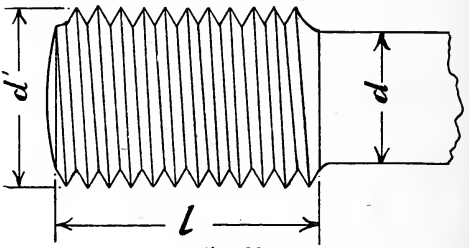


Fig. 23

NOTE—Upsetting reduces the strength so that bars having the same diameter at Root of thread as that of the bar invariably break in the screw end when tested to distinction, without developing the full strength of the bar.

It is therefore necessary to make up for their loss in strength by an excess of metal in the upset screw ends over that in the bar. The above table is the result of tests by The Carnegie Steel Co., and gives proportions that will cause the bar to break in the body of the bar.

To make one upset end for 5 in. length of thread, allow 6 in. length of rod additional.

Lengths of Threads Cut on Bolts.

Length of Bolts.	$\frac{1}{4}$ & $\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$ & $\frac{1}{2}$	$\frac{9}{16}$ & $\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
1 to $1\frac{1}{2}$ in.	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	.....	.....	.....	.....	.....
$1\frac{5}{8}$ " 2 "	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	.....	.....	.....
$2\frac{1}{8}$ " $2\frac{1}{2}$ "	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	.....	.....
$2\frac{5}{8}$ " 3 "	$\frac{7}{8}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	.....
$3\frac{1}{8}$ " 4 "	$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
$4\frac{1}{8}$ " 8 "	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$
$8\frac{1}{8}$ " 12 "	1	1	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	3
$12\frac{1}{8}$ " 20 "	1	1	$1\frac{1}{2}$	2	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	3

Bolts longer than 20 inches and larger than $1\frac{1}{4}$ inches in diameter will be threaded about 3 times the diameter of the rod.

STANDARD UPSETS

For Round and Square Bars

ROUND BARS							SQUARE BARS						
ROUND		UPSET					UPSET					SQUARE	
Diam.	Area	Diam.	Length	Add	Area at Root	Excess Area	Excess Area	Area at Root	Add	Length	Diam.	Area	Diam.
Inches	Sq. Ins.	Inches	Inches	Inches	Inches	0/0	0/0	Sq. Ins.	Inches	Inches	Inches	Sq. Ins.	Inches
5/8	0.307	7/8	4	4 1/2	0.420	36.8							5/8
3/4	0.440	1	4	3 7/8	0.550	24.4	20.6	0.694	3 1/2	4	1 1/2	0.563	3/4
7/8	0.601	1 1/8	4	5	0.891	48.3	16.3	0.891	4	4	1 1/4	0.766	7/8
1	0.785	1 3/8	4	4 3/8	1.057	34.7	29.5	1.295	4	4	1 1/2	1.000	1
1 1/8	0.994	1 1/2	4	3 7/8	1.295	30.3	19.7	1.515	4 1/2	4 1/2	1 5/8	1.266	1 3/8
1 1/4	1.227	1 5/8	4 1/2	3 7/8	1.515	23.5	31.1	2.049	4 1/2	4 1/2	1 7/8	1.563	1 1/4
1 3/8	1.485	1 3/4	4 1/2	3 1/2	1.744	17.4	21.7	2.302	4 1/8	5	2	1.891	1 3/8
1 1/2	1.767	2	5	4 5/8	2.302	30.3	34.0	3.023	4 3/4	5	2 1/4	2.250	1 1/2
1 5/8	2.074	2 1/8	5	4 1/4	2.651	27.8	29.6	3.410	4 5/8	5 1/2	2 3/8	2.641	1 5/8
1 3/4	2.405	2 1/4	5	4	3.023	25.7	21.3	3.716	4 1/4	5 1/2	2 1/2	3.063	1 3/4
1 7/8	2.761	2 3/8	5 1/2	4 1/8	3.410	23.9	31.4	4.619	5 1/8	6	2 3/4	3.516	1 7/8
2	3.142	2 1/2	5 1/2	3 7/8	3.716	18.3	27.7	5.107	4 3/4	6	2 7/8	4.000	2
2 1/8	3.547	2 5/8	5 1/2	3 5/8	4.155	17.1	20.2	5.430	4 3/8	6	3	4.516	2 1/8
2 1/4	3.976	2 7/8	6	4 5/8	5.107	28.5	28.6	6.510	5 1/8	6 1/2	3 1/4	5.063	2 1/4
2 3/8	4.430	3	6	4 3/8	5.430	22.6	33.8	7.518	6 1/8	7	3 1/2	5.641	2 3/8
2 1/2	4.909	3 1/8	6 1/2	4 3/8	5.957	21.3	30.7	8.170	6 1/4	8	3 5/8	6.250	2 1/2
2 5/8	5.412	3 1/4	6 1/2	4 1/4	6.510	20.3	35.0	9.305	6 3/4	8	3 7/8	6.891	2 5/8
2 3/4	5.940	3 3/8	7	4 1/4	7.088	19.3	32.1	9.994	6	8	4	7.563	2 3/4
2 7/8	6.492	3 5/8	8	5 1/2	8.170	25.9	37.0	11.329	8	9	4 1/4	8.266	2 7/8
3	7.069	3 3/4	8	5 1/4	8.641	22.2	41.7	12.753	7 1/2	9	4 1/2	9.000	3
3 1/8	7.670	3 7/8	8	5 1/8	9.305	21.3							3 1/8
3 1/4	8.29	4	8	4 7/8	9.994	20.7							3 1/4
3 1/2	9.621	4 1/4	9	5 1/4	11.329	17.7							3 1/2
3 3/4	11.045	4 1/2	9	4 3/4	12.753	15.5							3 3/4

From American Bridge Co.

To join two rods and afford a means to tighten them, a "turn buckle" is used, shown in the following table, Fig. 24. The proportions are in reference to the diameter of the threaded part.

In figuring the weight of long bolt the following table will be of assistance.

Let it be required to figure the weight of a 1″ tie rod or bolt with square head and nut, the length under the head being 12′-2″.

The weight of one foot of 1″ rod is 2.67 lbs. and multiplying this by 12 1-6 (12′ 2″ = 12 1-6 ft.) we get 32.48 lbs.

Adding to this 1.31 as the weight of a square nut and head would make 33.79 lbs. as the total weight and according to the above table the thread would be 3″ long (3 x diameter). If the rod was threaded on both ends it would weigh practically the same.

Weights of Nuts, Bolt Heads and Round Bars in pounds

Dia. of Bolt	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2½	3
Weight of Hex. Nut and Head	.017	.067	.128	.267	.43	.73	1.10	2.14	3.78	5.6	8.75	17.0	28.8
Weight of Sq. Nut and Head	.021	.079	.164	.320	.55	.88	1.31	2.56	4.42	7.0	10.5	21.0	36.4
Weight of Hex. Nut & Sq. Head	.019	.031	.144	.321	.542	.75	1.01	2.45	3.58	5.7	7.5	17.8	31.8
Weight of Round ar per foot	.167	.375	.367	1.043	1.502	2.044	2.670	4.173	6.008	8.178	13.60	21.25	30.60

EYE BARS.

Iron bars are generally made by the "top piling" process, loop piling being used in special cases.

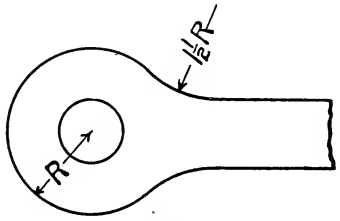


Fig. 25

Material for top piling being ordered in bar lengths as far as possible, the minimum thickness for bars is ½″.

Eye-bars for the same structure should, as far as possible, be made of uniform width and with same size of head at each end of bar. Fig. 25.

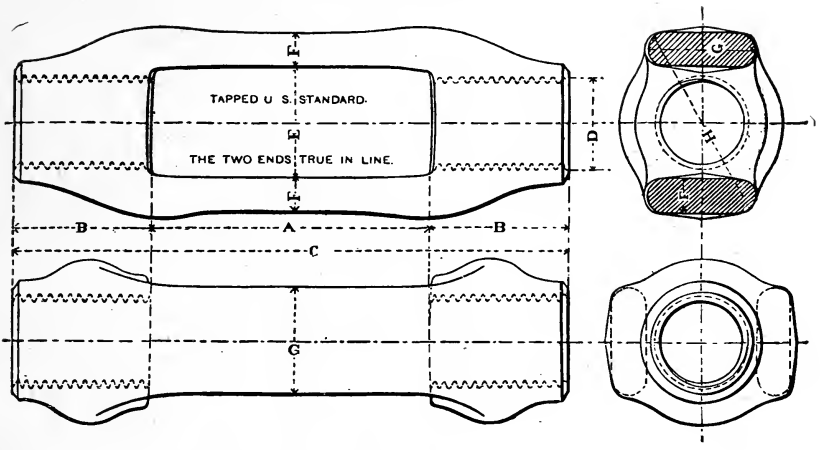
LOOP BARS.

Loop bars Fig. 26 are usually made of iron and the finished length, without adjustment will be given from back to back of eyes.

EYE BARS

Width of Bar	Min. Thickness of Bar	HEAD		
		Diam.	Max. Pin	Additional Material for Head
Inches	Inches	Inches	Inches	Ft.&inches
2	⅝	4¼	1¾	0– 7½
	"	5½	2¾	1– 0½
2½	¾	5½	2¼	0– 9½
	"	6½	3¼	1– 1½
3	¾	7	3	1– 3
	"	8	4	1– 6
4	¾	9½	4¼	1– 8
	"	10½	5¼	1–10
5	¾	11½	5	1– 9
	1	12½	6	2– 1
6	¾	13½	5½	1–11
	1	14½	6½	2– 2
7	⅞	16	6¾	2– 3
	1 5/16	17	7¾	2– 8
8	1	17	6½	2– 3
	1 1/16	18	7½	2– 6
	1⅛	18½	8	2–10
9	1⅛	19½	7¾	2– 6
		21½	9¾	3– 1
10	1⅜	22	9	2–11
	"	23	10	3– 3

TURNBUCKLES.



Size D.	A	B	C	E	F	G	H
3/8 In.	6 In.	9/16 In.	7 1/8 In.	9/16 In.	3/16 In.	1/8 In.	1 1/16 In.
7/16	6	21/32	7 5/16	5/8	1/4	5/8	1 3/8
1/2	6	3/4	7 1/2	5/8	1/4	5/8	1 3/8
9/16	6	27/32	7 11/16	13/16	5/16	3/4	1 9/16
5/8	6	15/16	7 7/8	13/16	5/16	3/4	1 9/16
3/4	6	1 1/8	8 1/4	1 1/16	11/32	7/8	2
7/8	6	1 5/16	8 5/8	1 1/4	3/8	1	2 1/4
1	6	1 1/2	9	1 5/16	7/16	1 1/4	2 7/16
1 1/8	6	1 11/16	9 3/8	1 7/16	1/2	1 1/4	2 9/16
1 1/4	6	1 7/8	9 3/4	1 5/8	1/2	1 1/8	2 3/4
1 3/8	6	2 1/16	10 1/8	1 11/16	1/2	1 5/8	3 1/16
1 1/2	6	2 1/4	10 1/2	1 3/4	5/8	1 3/4	3 3/16
1 5/8	6	2 7/16	10 7/8	2	5/8	1 7/8	3 1/2
1 3/4	6	2 5/8	11 1/4	2 1/16	5/8	2	3 3/4
1 7/8	6	2 13/16	11 5/8	2 3/16	11/16	2 1/8	3 7/8
2	6	3	12	2 3/8	11/16	2 1/4	4 1/4
2 1/8	6	3 5/16	12 3/8	2 1/2	23/32	2 1/2	4 1/2
2 1/4	6	3 3/8	12 3/4	2 11/16	13/16	2 1/2	4 3/4
2 3/8	6	3 9/16	13 1/8	2 3/4	13/16	2 3/4	4 7/8
2 1/2	6	3 3/4	13 1/2	3 1/16	27/32	3	5 3/8
2 5/8	6	3 15/16	13 7/8	3 1/8	15/16	3	5 9/16
2 3/4	6	4 1/16	14 1/4	3 1/4	15/16	3 1/4	5 3/4
2 7/8	6	4 5/16	14 3/8	3 7/16	1 1/32	3 1/4	6 1/16
3	6	4 1/2	15	3 5/8	1 1/32	3 1/2	6 3/8
3 1/8	6	4 7/16	15 3/4				
3 1/2	6	5 1/4	16 1/2	Dimensions E F G H depend upon the specifications			
3 3/4	6	5 5/8	17 1/4				
4	6	6	18	of the Bars with which the Turnbuckles			
4 1/4	9	6 1/4	21 1/2				
4 1/2	9	6 3/4	22 1/2	are to be used			
4 3/4	9	7 1/4	23 1/2				
5	9	7 1/2	24				

Standard Length, 6 inches between Heads, (A) for all Sizes.

Second	(A)
Third	(A)
Fourth	(A)
Fifth	(A)
Sixth	(A)
Seventh	(A)
Eighth	(A)
Ninth	(A)

Fig. 24

For rods with adjustment, length will be given from back of eyes to end of rod. For those bent, from inner corner of bend in eye to end of rod.

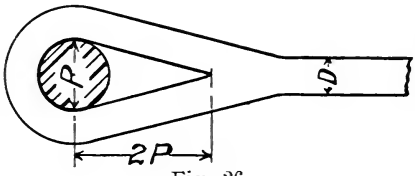


Fig. 26

When flat bars with sleeve nut adjustment are made of iron or steel they are upset at the screw end, and the material for each bar ordered for one length accordingly. It has been noted in the blue prints of a well known firm that the minimum length of finished up-

If it becomes necessary to make them shorter order stock for two rods including the amount for turning the loop and making the upset, these to be cut after upsetting and the loops turned.

If forked loop is desired, two rods without loops and after upsetting and cutting in two, the forks are welded on. set rod which can be made in a machine is 24 inches fo reither loop or fork.

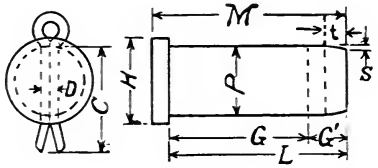


Fig. 27

PINS.

Pins are used extensively in structural work, especially the brace rods or tie rods in the buildings and the eyebars in bridge work, Fig. 27.

The head of the pin is slightly larger than the body and the end is tapered to aid in entering the holes.

The pins must be calculated to stand a shearing stress of about 38,000 lbs. The grip of a pin is the clear distance between head and nut or between nuts. In figuring lengths of pins, $\frac{1}{16}$" will be allowed for each space between eye hose, and in order to be sure that all distance between shoulders is $\frac{1}{2}$" greater than the grip of the pin.

The holes are usually $\frac{1}{32}$ more in diameter than the pin.

Rough pins in bored holes have $\frac{1}{32}$" play. Rough pins in rough holes have $\frac{1}{8}$" play.

PINS WITH COTTERS

All Dimensions in Inches

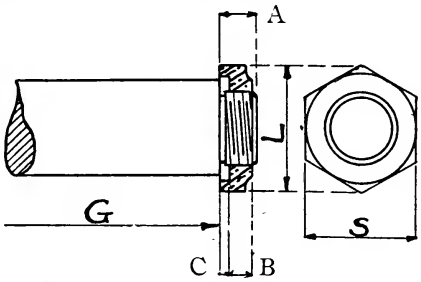
Diam. of Pin	PIN		HEAD		COTTER		ADD TO GRIP	
P	Diam. of Pin-hole	Taper at End T	H	T	C	D	M	L
1	$1\frac{1}{32}$	$\frac{5}{16}\times\frac{1}{16}$	$1\frac{1}{4}$	$\frac{1}{2}$	$1\frac{3}{4}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{5}{8}$
$1\frac{1}{4}$	$1\frac{9}{32}$	$\frac{5}{16}\times\frac{1}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$	2	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{5}{8}$
$1\frac{1}{2}$	$1\frac{17}{32}$	$\frac{5}{16}\times\frac{3}{32}$	$1\frac{3}{4}$	$\frac{1}{2}$	$2\frac{1}{4}$	$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$
$1\frac{3}{4}$	$1\frac{25}{32}$	$\frac{7}{16}\times\frac{3}{32}$	2	$\frac{1}{2}$	$2\frac{3}{4}$	$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$
2	$2\frac{1}{32}$	$\frac{1}{8}\times\frac{1}{8}$	$2\frac{1}{8}$	$\frac{5}{8}$	3	$\frac{5}{16}$	$1\frac{1}{8}$	1
$2\frac{1}{4}$	$2\frac{9}{32}$	$\frac{1}{16}\times\frac{1}{4}$	$2\frac{5}{8}$	$\frac{5}{8}$	$3\frac{1}{4}$	$\frac{5}{16}$	$1\frac{1}{8}$	1
$2\frac{1}{2}$	$2\frac{17}{32}$	$\frac{3}{16}\times\frac{3}{32}$	$2\frac{7}{8}$	$\frac{5}{8}$	$3\frac{3}{4}$	$\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{1}{4}$
$2\frac{3}{4}$	$2\frac{25}{32}$	$\frac{3}{16}\times\frac{3}{32}$	$3\frac{1}{8}$	$\frac{5}{8}$	4	$\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{1}{4}$
3	$3\frac{1}{32}$	$\frac{3}{16}\times\frac{3}{16}$	$3\frac{1}{2}$	$\frac{5}{8}$	5	$\frac{5}{16}$	$1\frac{7}{8}$	$1\frac{1}{4}$
$3\frac{1}{4}$	$3\frac{9}{32}$	$\frac{3}{16}\times\frac{3}{16}$	$3\frac{3}{4}$	$\frac{3}{4}$	5	$\frac{3}{8}$	$1\frac{7}{8}$	$1\frac{1}{4}$
$3\frac{1}{2}$	$3\frac{17}{32}$	$\frac{3}{16}\times\frac{3}{32}$	4	$\frac{3}{4}$	6	$\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{1}{4}$
$3\frac{3}{4}$	$3\frac{25}{32}$	$\frac{7}{16}\times\frac{3}{32}$	$4\frac{1}{4}$	$\frac{3}{4}$	6	$\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{1}{4}$

M=T+Grip+(Amt. add to Grip)

PINS

WITH

LOMUS NUTS



All Dimensions in inches.

Diameter of Pin	PIN			STANDARD DIMENSIONS 6 Threads per Inch			NUT			
	Screw		Add to Grip				Diam. of Rough Hole	Short Diam.	Long Diam.	Weight in Lbs.
	Diam.	Length		A	B	C		S	L	
2	1½	1½	¼	1½	1	⅜	1 5/16	3¼	3¾	2.5
2¼	1½	1½	¼	"	"	"	1 5/16	3¼	3¾	2.5
2½	2	1½	¼	"	"	"	1 13/16	3¾	4 5/16	2.5
2¾	2	1½	¼	"	"	"	1 13/16	3¾	4 5/16	2.5
3	2½	1½	¼	"	"	"	2 5/16	4½	5 3/16	3.0
3¼	2½	1½	¼	"	"	"	2 5/16	4½	5 3/16	3.0
3½	2½	1½	¼	"	"	"	2 5/16	4½	5 3/16	3.0
3¾	3	1⅛	½	1⅞	1¼	½	2 13/16	5	5¾	5.5
4	3	1⅛	½	"	"	"	2 13/16	5	5¾	5.5
4¼	3½	1⅛	½	"	"	"	3 5/16	5¾	6⅝	7.0
4½	3½	1⅛	½	"	"	"	3 5/16	5¾	6⅝	7.0
4¾	3½	1⅞	½	"	"	"	3 5/16	5¾	6⅝	7.0
5	4	1⅛	½	"	"	"	3 13/16	6½	7½	8.5
5¼	4	1⅛	½	"	"	"	3 13/16	6½	7½	8.5
5½	4½	1⅛	½	"	"	"	4 5/16	7	8⅛	11.0
5¾	4½	1⅞	½	"	"	"	4 5/16	7	8⅛	11.0
6	4½	1⅛	½	"	"	"	4 5/16	7	8⅛	11.0
6¼	5	2⅜	¾	2⅜	1½	¾	4 13/16	7¾	8 15/16	12.0
6½	5	"	"	"	"	"	4 13/16	7¾	8 15/16	12.0
6¾	5½	"	"	"	"	"	5 5/16	8¼	9½	13.5
7	5½	"	"	"	"	"	5 5/16	8¼	9½	13.5
7¼	5½	"	"	"	"	"	5 5/16	8¼	9½	13.5
7½	5½	"	"	"	"	"	5 5/16	8¼	9½	13.5
7¾	6	"	"	"	"	"	5 5/16	9	10⅜	17.0
8	6	"	"	"	"	"	5 13/16	9	10⅜	17.0
8¼	6	"	"	"	"	"	5 13/16	9	10⅜	17.0
8½	6	"	"	"	"	"	5 13/16	9½	10⅞	
8¾	6	"	"	"	"	"	5 13/16	10½	12⅛	
9	6	"	"	"	"	"	5 13/16	10½	12⅛	
9¼	6	"	"	"	"	"	5 13/16	10½	12⅛	

NOTE:—To obtain grip "G" add $\frac{1}{16}$" for each bar, together with amount given in table.

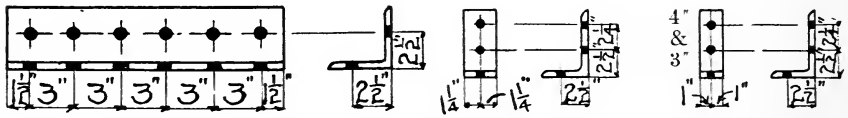
CHAPTER IV.

CONNECTION ANGLES AND ANCHORS

The beams or members of a structural frame must be held together and much is done by means of connection angles. These are riveted to the webs of the beams or channels and usually carry all the strain, but in a few cases an angle is placed under a beam to help support the load.

These connection angles have been standardized by several prominent manufacturers and those of the Carnegie Steel Co., are here given. They are shown for the several sizes of beams that are in general use. Fig. 28.

For 24″ Beams

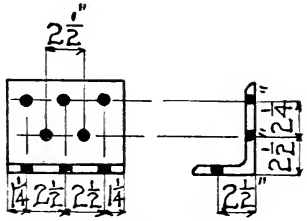


2-Ls 4″×4″×$\frac{7}{16}$×′-6″
Weight 43 lbs.

For 6″-2 Ls 6×4×$\frac{7}{16}$×3″-
Weight 9 lbs
For 5″-2 Ls 6×4×$\frac{7}{16}$×2$\frac{1}{2}$-
Weight 8 lbs.

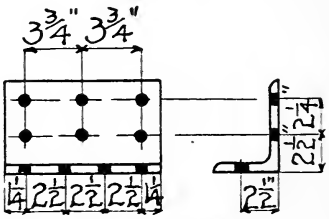
2 Ls 6×4×$\frac{7}{16}$
×2″
Weight 7 lb.

12″



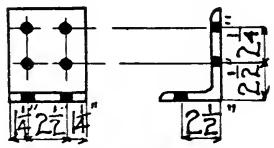
2-Ls×4″×$\frac{7}{16}$×7$\frac{1}{2}$″-Wt. 23 lbs.

15″



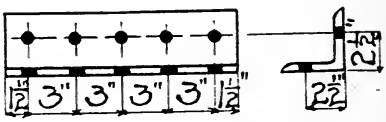
2 Ls-6×4×$\frac{7}{16}$×10″-Wt. 31 lbs.

7″, 8″
9″ &
10″



2 Ls-6×4×$\frac{7}{16}$×5″ Wt. 16 lbs.

18″
&
2′



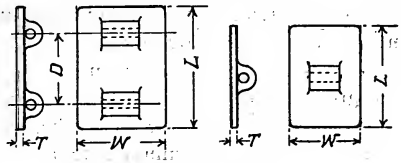
2-Ls 4×4×$\frac{7}{16}$×1′-3″-Wt. 36 lb.

Fig. 28

All rivets in standard framing angles are $\frac{3}{4}$″ diam. Weights of standard framing angles include weight of shop and field rivets.

SEPARATORS.

All dimensions in inches.

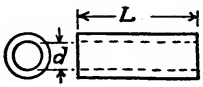


Cast Iron

Size of Beam	STANDARD DIMENSIONS				WEIGHTS				Size of Beam
	Distance between Holes D	Min. Width of Seperator W	Length of Separator L	Thickness T	Separator	Incr. in Wt. of separat'r for 1" add'l spread of I	Bolts and Nuts	Incr. in Wt. of Bolts for 1" add'l spread of I	
24	12	6¾	20	⅝	28.00	4.50	2.84	.248	24
20	12	6	16	"	23.00	3.20	2.70	"	20
18	9	5¾	14	"	21.00	2.75	2.60	"	18
15	7½	5½	11½	½	14.75	1.80	2.40	"	15
12	5	5	8¾	"	9.75	1.50	2.28	"	12
10	One Hole	4¾	7½	"	6.50	1.25	1.08	.125	10
9	"	4¼	6½	"	5.75	1.10	1.04	"	9
8	"	4	5½	"	4.50	1.00	1.01	"	8
7	"	3½	5	"	3.75	.75	0.95	"	7
6	"	3¼	4½	"	2.25	.60	0.93	"	6

Bolts ¾" diam.

Beams should be spread so that width of separator "W" comes in even in even quarters of an inch.



Size of Beam	STANDARD DIMENSIONS				WEIGHTS				Size of Beam
		Min. length of Separator L	Nominal Diameter of Pipe d		Separator	Incr. in Wt. of separat'r for 1" add'l spread of I	Bolts and Nuts	Incr. in Wt. of Bolt for 1" add'l spread of I	
5		3	¾		.28	.1	.9	.124	5
4		2¾	"		.26	"	.87	"	4
3		2½	"		.21	"	.82	"	3

Bolts ¾" diam.

From American Bridge Co.

GENERAL INFORMATION ABOUT PLATES

To find the size or location of any object on a plate, take the dividers and set them for the distance between the border lines at the top of the plate. With this distance step off the amount required, calling each step, ½ in. For instance, on plate No. 1, the distance from the border to center of first rivet is two and one-half steps, or 1¼ in.

Where a dimension is given in the description of a plate it should be followed, even if it does make a view slightly out of line with some other view as shown on the plate. For example, Plate 1, the I-beam and Angle when drawn to the dimensions given will bring the center of the left view directly under the first rivet, but the views do not show that now.

By stepping off the distance of the ragged line of the Channel it is found to be about 1¼ in. from the right border line.

All mention to "border line" refers to the inside one, the outside line is the edge of the finished sheet when trimmed, 14 in. x 19 in.

See plate on page 54 for style of lettering to use on the drawings. All inscriptions should be ⅛ in. high.

DESCRIPTION OF PLATE NO. 1

This plate consists of elementary views of some structural shapes, drawn in at different scales.

Draw a row of rivets as shown. The top surface of the plates fastened by the rivets is 1⅝ in. from the top border line. The vertical center lines of the rivet on the left is 1¼ in. from the left border line and the others are 2 in. apart. Draw these rivets from the proportions given by Fig. 15, using a diameter of ½ in. (scale full size), Plates are ⅜ in. thick. The spacing for the "I-beam and Angle" can be obtained from description of connection angles in Chapter IV. Make it an 18 in.-55 lb. beam (scale 3 in. = 1 ft.), and draw the top line 3½ in. from the upper border. The center line of the end view is 1¼ in. from the left border line. Find size of rivets and holes in Chapters II and IV.

The next figure represents a standard 3¼ in. x 5 in. x 3¼ in. x ½ in. z-bar (scale 6 in. = 1 ft.). The blank dimension represents the gauge and can be obtained from table on page 19. Show holes for ¾ in. rivets in end and side views. The channel shown is a standard 12 in.-31.5 lb. (scale 3 in. = 1 ft.), see table, page 6, for the gauge, thickness of web, etc.

The spacing for the standard 4 in. angle, at the left, (scale 3 in.=1 ft.) will be found in Chapter IV, and should be drawn for a 20 in. beam connection. Draw the bottom line of the angle 1¼ in. from the lower border line, and the left line of the left-hand view, ½ in. from the left border line. The distance apart is governed by the thickness of the beam. The blank dimensions for the angles can be filled in from table.

For the "Beam Connection," made the main beam (the beam on the left) 12 in. (scale 3 in. = 1 ft.) and the opposite beam 8 in. Their bottom line 1¼ in. from lower border line, and it remains with the student to fit in the connecting angles.

Note A.—When beam frame opposite each other into another beam with a web thickness less than 9-16 in., or where beams of short span lengths are loaded to their full capacity, it may be necessary to use angles of greater strength than the standard here shown.

The view "Angle on Plate" shows a few conventional signs for riveting. Make the bottom edge of the plate 2½ in. from the lower border. The plate is 5 in. wide (scale 6 in. = 1 ft.) and the

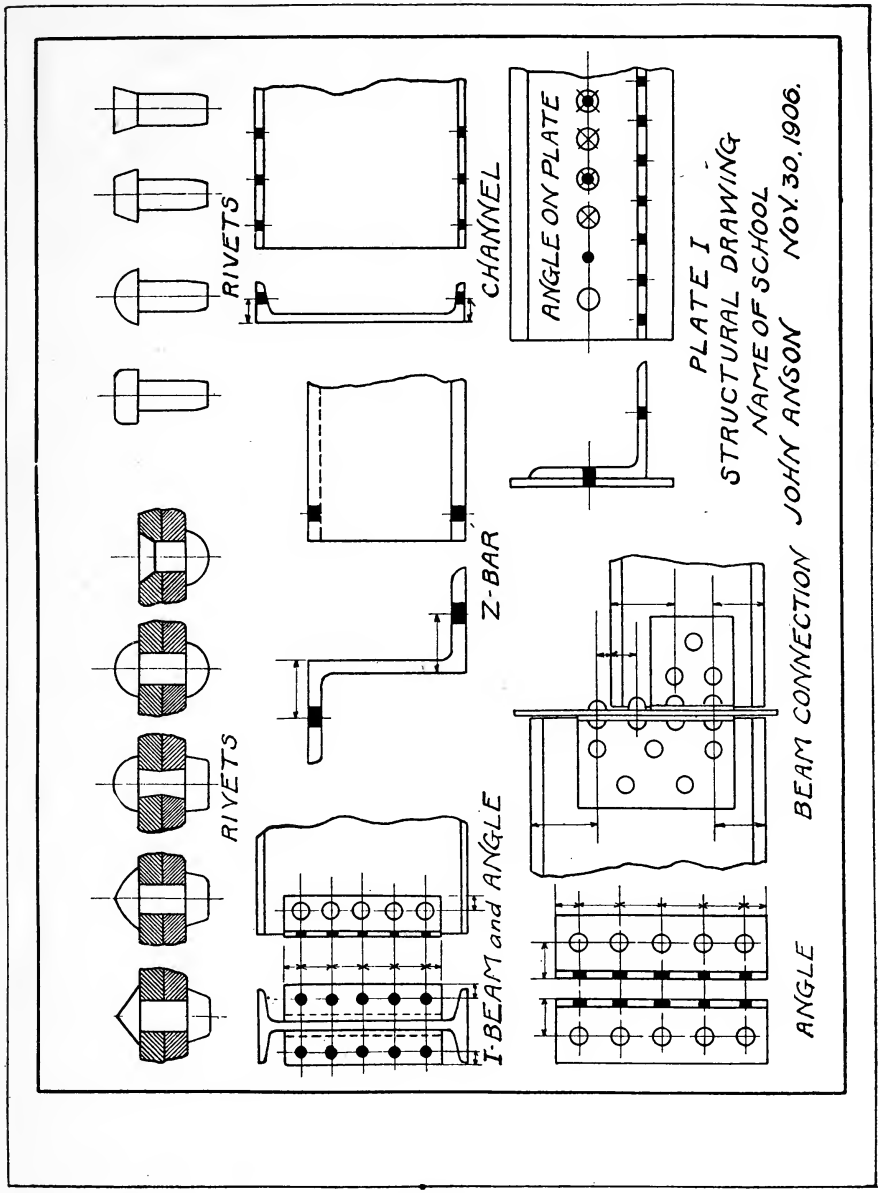

RIVETS
I-BEAM and ANGLE
RIVETS
Z-BAR
CHANNEL
ANGLE ON PLATE
ANGLE
BEAM CONNECTION JOHN ANSON NOV. 30, 1906.
PLATE I
STRUCTURAL DRAWING
NAME OF SCHOOL

Plate 1

angle is a standard 4 in. x 4 in. x ½ in. with spacing for ¾ in. rivets.

The title for the plates should be put in the lower right-hand corner. There are four lines of ⅛ in. letters. The space between the lines is ⅜ in. The center line of the title should be about 2¼ in. from the right border line, and the bottom of the lowest line of letters ¼ in. from the lower border line.

(Read page 55 carefully before lettering your drawing.)

DESCRIPTION OF PLATE NO. 2

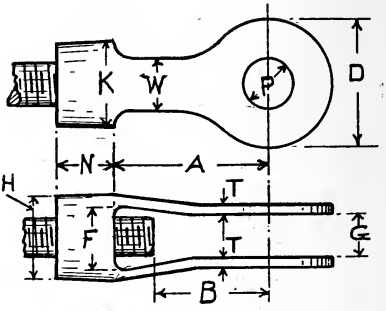
The center line of bolts, pins, etc., is 1½ in. from the border line. Using this center line draw a standard bolt showing a square and a hexagonal head, also a square and a hexagonal nut. Using a scale of 1 in. = 1 ft., make the bolt 6 in. in diameter and 30 in. long. The proportionate sizes for the heads and nuts will be found in table, in Appendix.

With the same center line draw a pin with lomas nut. The vertical center line of the head is 1⅞ in. from the right-hand border line. Using a scale 3 in. = 1 ft., draw a 7 in. pin and fill in the blank dimension spaces from table, page 25.

The second center line is 3⅞ in. from the top border, while the vertical center line of the section of the sleeve nut shown is 1⅜ in. from the left. Make the diameter of the screw 3½ in. to a scale of 3 in. = 1 ft. Make the diameter of the screw of the turnbuckle on the next line 4 in. to the same scale and draw both from the dimensions found in table, page — and 23.

Draw the cotter pin shown on the third line with a diameter of 3 in. to a scale of 4 in. = 1 ft. The vertical center line of the end view is 5⅞ in. from the right border. See table, page 24 for the proportionate dimensions. Grip 9 in.

The third center line is 7 in. from the top. The vertical center line of the pin hole of the clevis on the right is 1½ in. from the right border line. With a scale of 3 in. = 1 ft. draw the clevis according to sizes here given.



A=9″ B=8″ D=7″
P=4″ F=3¼″ N=3½″
W=3¼″ T=⅛″ H=F+2T

With horizontal and vertical center lines 3¼ in. and 5¾ in. from the lower and left border lines respectively draw an adjustable eye-bar from sketch. (Taken from engineer's note book): Make the diameter of the head 7 in. to a scale of 3 in. = 1 ft.

Draw a loop rod with a pin diameter of 5 in. (scale 2 in. = 1 ft.) and use corresponding sizes found in table —. The horizontal center line is 1⅜ in. from the lower border while the vertical center line of the pin is 1⅛ in. from the left border line.

The vertical center line of the title of the plate should be aproximately 4 in. from the right border line.

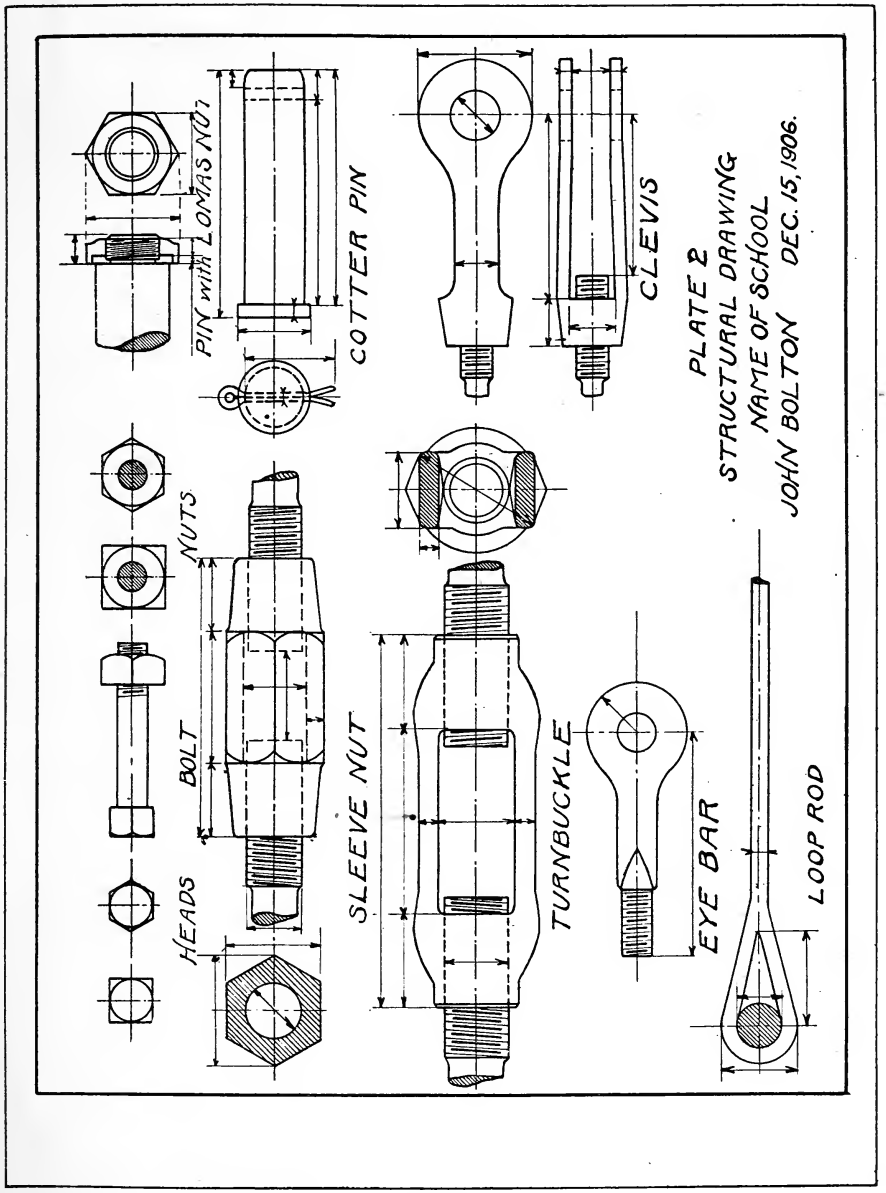

PIN with LOMAS NUT
COTTER PIN
CLEVIS
PLATE 2
STRUCTURAL DRAWING
NAME OF SCHOOL
JOHN BOLTON DEC. 15, 1906.
NUTS
BOLT
HEADS
SLEEVE NUT
TURNBUCKLE
EYE BAR
LOOP ROD

Plate 2

DESCRIPTION OF PLATE NO. 3

Plate three illustrates several different methods of anchoring, together with two standard separators used in beam girder work.

The bases of the beams in the illustrations of anchors Nos. 1, 2 and 3 are 2 in. from the top border line. The right edges of the beams are 4½ in., 10 in. and 15½ in. from the left border line. Draw this entire plate to a scale of ¾ in = 1 ft.

Anchor No. 1 consists of simply an iron bar ¾ in. round, 2 ft.-0 in. long, bent as shown. Anchor No. 2 is made up of two angles, 6 in. x 7-16 in. x 0 ft.-3 in., bolted as shown in the field with ¾ in. bolts. In anchor No. 3 a 3 in. x ⅜ in. flat bar, 1 ft.-1 in. long winds around a ¾ in. round bar, 1 ft.-0 in. long. This is put together in the field with ¾ in. bolts. These beams are 15 in.-40 lb.

The center line of the bolt in anchor No. 4 is 6¾ in. from the top border. The left edge of the wall is 1½ in. from the left border, and the wall is 3 ft.-5 in. thick (scale ¾ in. = 1 ft.). Anchor No. 4 consists of a ¾ in. bolt with a plain, square washer or cast iron rosette, and holding a 15 in.-60 lb. channel.

Draw a hacked bolt and a split bolt as shown, (¾ in. diameter), which are used to hold down a girder.

Draw an expansion bolt, 1 in. diameter holding a 20 in.-40 lb. channel.

Draw two separators. Make the two hole separators for a 20 in. beam, and the one hole for a 10 in. beam. See table, page 27.

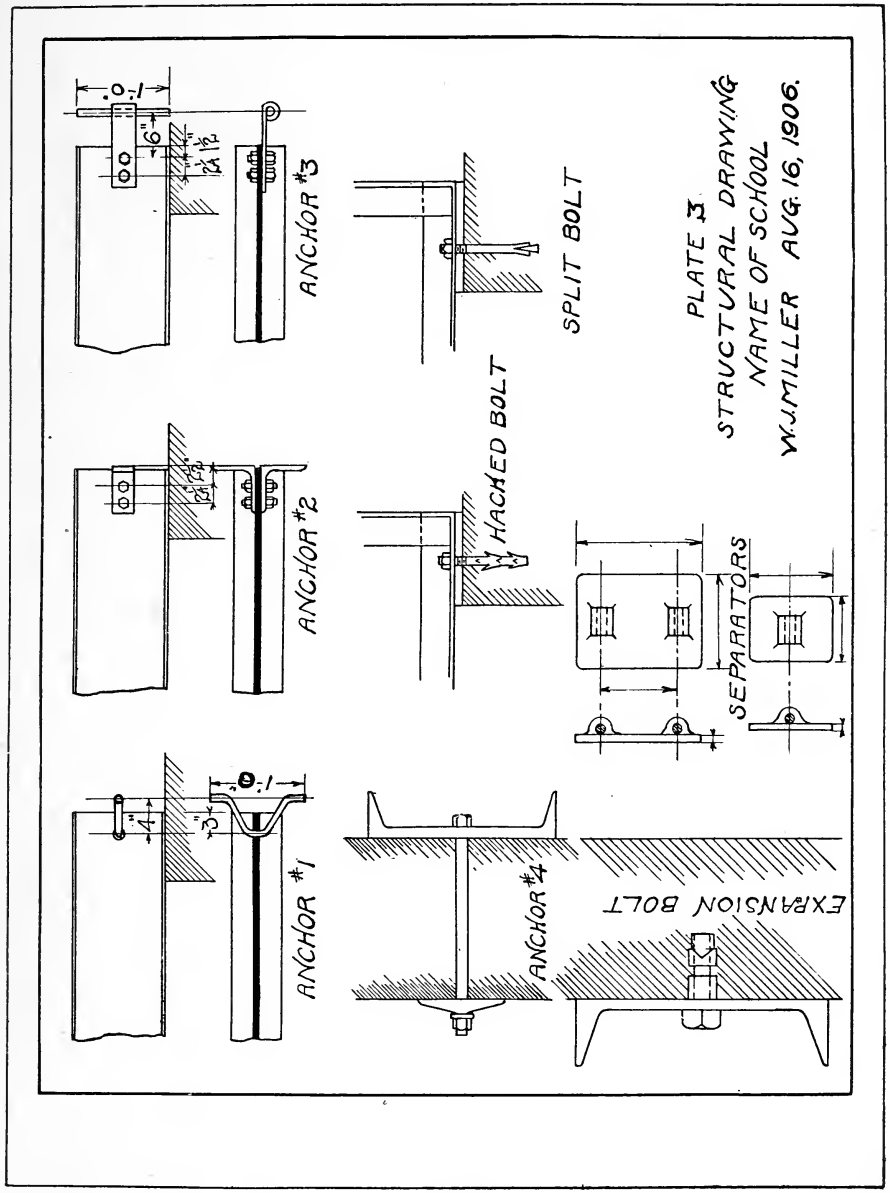


PLATE 3
STRUCTURAL DRAWING
NAME OF SCHOOL
W.J.MILLER AUG. 16, 1906.
ANCHOR #1
ANCHOR #2
ANCHOR #3
ANCHOR #4
HACHED BOLT
SPLIT BOLT
SEPARATORS
EXPANSION BOLT

Plate 3

CHAPTER V.

STRENGTH OF MATERIALS.

This subjct is in itself a large one. It will not be possible in this small work to cover the matter in an extended manner.

It is only with a view to acquaint the student with some of the leading points in "Strength of Materials" that the following matter was compiled.

DEFINITIONS.

The *load* of any part of a machine or structure is the total of all external forces acting upon it.

A *live* load is a variable one, applied and removed continuously.

A *dead*, or constant load, is that which has a continuous steady action on the machine or structure.

The *useful* load is that which the machine or structure is designed to carry outside of itself.

Resistance of a material to change its form is due to the inherent cohesive force of its molecules.

Elasticity or spring, is the characteristic of the material to regain its original form after an external load has been removed.

The elastic limit is the maximum extension or compression to which a material can be subjected without permanent set.

Stress and *Strain*—If we were to make any number of sections of a body and it were found that there was no tendency for one part of it to move relative to any other part, that body is said to be in a *state of case;* but when other part, we know that the body is acted upon by equal and opposite forces and the body is said to be in a *state of stress.*

Thus, if we were to make a series of saw cuts in a plate of metal and the cuts were found to open or close before the saw was through, we would know that the plate was in a state of stress because the one part tends to move relatively to the oher.

The stress is due either to external forces acting on the plate or to internal initial stresses in the material, such as is often found in badly handled castings or in cold rolled shafting.

The strain of a body is the change of form or dimensions that it undergoes when placed in a state of stress.

If the load does not place the material beyond its elastic limit, the strain will disappear when the stress is removed.

No bodies are absolutely rigid; they all yield, or are strained more or less, when subjected to stress, however small.

A material may be loaded so that the stress will act in one or a combination of forms; if pulling, in *tension;* if pushing, in *compression;* if cross-cutting, in *shear;* if twisting, it produces *torsion,* and the body may be put under both a push and a pull, as in bending.

Then the strength of a material is its resistance to one or the other of these forms of stress: *Tensile* strength, to resist being pulled apart, as a rope; *compressive* strength, as in the foundation of a house; *tortional* strength, as in a shaft; *shearing,* as in the case of a rivet or bolt, though these are often in tension, too.

The cutting of a plate with a pair of shears is a better example of the latter kind of strength.

Bending is a combination of tension and compression.

When the molecules of a body part, it is said to be fractured. A fracture ma yappear when the load becomes great enough to cause permanent set.

The final, or ultimate strength, is the smallest load that will fracture a member, and machine members should be designed strong enough to resist permanent set under the maximum load.

Stresses are measured in pounds, tons, or kilograms.

A *unit stress* is the amount of stress on a unit of area, and is expressed in pounds per square inch, or in kilograms per square centimeter.

Within the elastic limit, it is found that stress and strain are proportional, and this had led to an investigation to determine some means of concisely expressing the amount of strain that a body undergoes when subjected to a given stress.

The usual method of doing this is to state of the intensity of stress required to strain the bar by an amount equal to twice its own length, assuming the *material to remain perfectly elastic.*

It need hardly be pointed out that no material used by engineers will remain perfectly elastic when pulled out to twice its original length; in fact, very few materials will stretch much more than *one thousandth* of their length and remain elastic.

This ratio of strain to stress is known as the *modulus of* (or measure of) *elasticity,* and may be expressed thus:—

$$E.— \frac{\text{Stress per sq. in. in lbs.}}{\text{Strain per inch of length.}}$$

When all is within the elastic limit.

This formula was deduced by Dr. Thomas Young in 1826 and is known as "Young's Formula."

From the above it might be said that the Modulus of Elasticity is the ratio of a unit stress to a unit strain.

The values of the *modulus of elasticity* for different material is given in the table under heading of "Data From Experimental Sources."

When the machine or structure is being designed, we would not want to put on it a useful or working load equal to its ultimate or breaking strength for signers who are acquainted with the load, and is known as the *factor of safety.*

The factor of safety for a piece to be designed is the ratio of the ultimate strength to the proper allowable working strength.

Thus: If *St* be the ultimate, *S* the breaking strength, and *f* the factor of safety, then

$$f = \frac{St}{s} \text{ and } St = fs.$$

The factor of safety is alway · n abstract number, which indicates ... number of times the working stress may be multiplied before the rupture of the body will take place.

It is evident that working strees should be lower where shocks occur than where a steady even load is applied, hence the factor of safety would be higher.

In a building the working stresses are steady; in a bridge they vary, and the factor in the first case could be small while in the latter much greater.

The following are average values of the allowable factors of safety commonly employed in American practice:

Material.	For steady stress.	For varying stress.	For shocks.
Timber	8	10	15
Brick & stone..	15	25	30
Cast iron	6	15	20
Wrought iron..	4	6	10
Steel	5	7	15

These values are subject to considerable variation in particular instances, not only on account of the different qualities and grades of the material, but also on account of the varying judgment of designers.

They will also vary with the range of varying stress so that different parts of a bridge will have very different factors of safety.

CHAPTER VI.

BEAMS AND GIRDERS.

Beams for supporting loads in building or bridge work may be either solid or of the built-up type.

Of the first named, the I-beam or channel is the most common while the latter is made up of a plate for the web and angles for the flanges.

The distinction between beam and girder is not noticeable for a "built-up beam" is a common expression yet the word girder may apply more closely to built up sections of considerable lengths and depths. The distance between supports is called the "span" and is usually denoted in feet. When supported near each end it is known as a simple beam but if a portion of it overhangs the support that part is called a *cantilever.*

Beams carry their load in several ways, evenly distributed, concentrated at one point or at several points. The beams of a floor are considered to carry the load uniformly distributed. Shafting may be considered as beams supported at the hangers but loaded at various points.

The pedal of a bicycle is an illustration of a cantilever beam and is subject to a bending action while the one uniformly loaded is in a position to be sheared right off close to the supports.

While a loaded beam is subject to shearing strains, these are very easily calculated and are very rarely considered as a possible cause of failure. We will spend but little time considering them, and will concentrate our attention on the methods for calculating what is known as the bending moment, for it is this that causes failure in almost every case.

Two general cases present themselves. The first is where a beam is set solidly in the wall at one end only, as in Fig. 29, and the second is where it is supported at both ends, as in Fig. 30. We will first consider the case of Fig. 29,

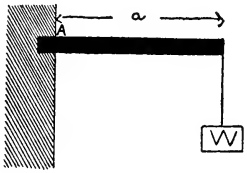


Fig. 29.

where but one end of the beam is supported, and where the weight is applied at the extreme end away from the support. In this case the maximum bending moment is located at the point of support, that is just where the beam enters the wall, and it is here that failure is most liable to occur. This bending moment is measured by the product of the weight, by the distance from the wall, which is marked "a" in the cut. The weight is usually taken in pounds

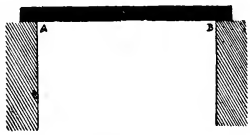


Fig. 30.

and the distance in feet. Thus if the distance "a" is 6 feet and the weight "W" 25 pounds, the bending moment at the point A is $25 \times 6 = 150$ pounds-feet. If in this case the weight is uniformly distributed, as, for instance, the weight of the beam itself, it may be taken as if located at its center.

Suppose the weight "W" in Fig. 29 is

evenly distributed over the length of the beam as in Fig. 31. Then we may consider the whole weight as if all located at its center, and to get the maximum bending moment, which is, as before, at the point A, we multiply the weight "W" by the distance to its center of gravity ½a. In other words, a beam loaded with a uniformly distributed load, as in Fig. 31, will support twice the load it will when the load is all placed at the extreme end, as in Fig. 29.

The same general method applies to loads distributed in any manner on a beam with but one support. The maximum bending moment is always at the point of support, that is at the point A, and is equal to the sum of each of the weights on the beam multiplied by their distances from A. Thus, if a beam is loaded, as in Fig. 32, with three weights, one of 5 pounds at a distance of 2 feet, another of 3 pounds at 5 feet and another of 7 pounds at 7 feet, then the bending moment at the point A, which is the maximum, is the sum of all these products, that is $(5 \times 2) + (3 \times 5) + (7 \times 7)$, which equals $10 + 15 + 49 = 74$ pounds-feet.

There is a shearing strain in Figs. 29, 31 and 32 equal to the total weights, including the weight of the beam itself. Neglecting the weight of the beam, which is not given, there is a total shearing strain at the point A in the problem in Fig. 32 of $5 + 3 + 7 = 15$ pounds. The shearing strain is always a maximum at one of the points of support, and is equal to the amount of weight supported at that point. If there is but one point of support there is no question of where the maximum shearing strain is and what it amounts to, as all of the weight is supported there. By dividing this total shearing strain by the sectional area of the beam the shearing strain per square inch can be arrived at and the possibility of failure from this cause noted.

We now come to the consideration of the case where the beam is supported at both ends, as in Fig. 30. The first thing to do in this problem is to find how the weight is distributed between the two supports. Starting at either end, as, for instance, A Fig. 30, take every weight on the beam and multiply it by its distance from this end (A) and add these products together. Divide this

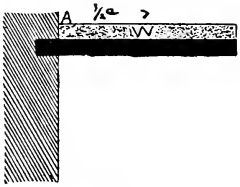


Fig. 31

sum by the distance between the supports AB and the results will be the weight supported by the end B; that is, the end opposite to that from which the start was made. A distributed weight may be considered to be entirely located at its center gravity. Such a load is the weight of the beam itself, which, if the beam is uniform, will be evenly divided between the two supports because its center of gravity is half way between them.

To find the weight which is supported by the end A we might proceed as we did in finding the weight supported at B, only the rule is reversed in this, that instead of starting at the end A, we start at the end B, multiply every weight by its distance from B, summing up these products and finally dividing by the distance between supports to find the weight supported at the end A, opposite to the one from which we started. By far the easier way, however, after having found the weight supported by one end, is to subtract that from the total load on the beam, which will naturally leave the portion supported by the other end.

As an example let us take the arrangement shown in Fig. 33. Starting at the end A we first come to the weight

11 pounds, at a distance of 2 feet; next to a weight of 17 pounds at a distance of 7 feet, and last to a weight of 21 pounds at a distance of 10 feet. $11 \times 2 = 22$, $17 \times 7 = 119$, $21 \times 10 = 210$. $22 + 119 + 210 = 351$. The distance betwen supports is 14 feet, so, dividing 351 by 14 gives us the weight supported at B, or 25 pounds, very nearly.

Again starting at B we first come to

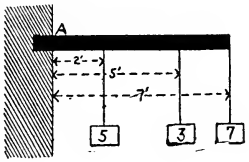


Fig. 32

the weight 21 pounds at a distance of 4 feet; next to a weight of 17 pounds at a distance of 7 feet, and last to a weight of 11 pounds at a distance of 12 feet. $21 \times 4 = 84$, $17 \times 7 = 119$, $11 \times 12 = 132$. $84 + 119 + 132 = 335$. Dividing this by the total distance between supports (14 feet) gives us the weight supported at A as follows:

$335 \div 14 = 24$ (very nearly).

It should be noted that the weight supported at A plus the weight supported at B is 49 pounds ($24 + 24$), and this is also the total load on the beam ($11 + 17 + 21 = 49$). If this test does not work out, an error has been made somewhere.

When the division of the load between the two supports has been arrived at, a vertical line may be drawn which will indicate a division of the beam into two portions, leaving the portion of the load carried by each support adjacent to it. That is, we may divide the beam into two portions, each portion of which is theoretically supported at its own end. We will call the line which divides the beam into these two portions "the dividing line." In Fig. 33, since the weight supported at A is 24 pounds, we may assume that the 11-pound weight is entirely supported at this end and that

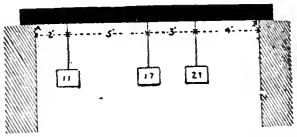


Fig. 33

13 pounds of the 17-pound weight is also supported at this end. The 21-pound weight is entirely supported at B and 4 pounds of the 17-pound weight is also supported at B. In other words, if a line be drawn dividing the 17-pound weight so that 13 pounds is towards A, and 4 pounds towards B, then the two portions into which the beam is divided by this line may be each considered to be supported by its own adjacent end. It is under this dividing line that the bending moment is a maximum, and it is here that the beam is most liable to give way. Sometimes the division line does

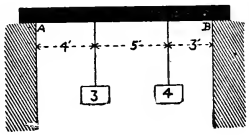


Fig. 34

not divide a weight. Such a case is given in Fig. 34, where the dividing line is anywhere between the two weights. This may be seen by calculating the distribution of the load between the supports, when it will be found that B supports 4 pounds and A 3 pounds. This puts the division anywhere between the two weights and the bending moment is the same anywhere in this section of the beam and is also a maximum. If we neglect the weight of the beam itself the bending moment is always the same at any points between adjacent weights, but the maximum must always divide the beam according to the rules previously given.

Referring to Fig. 33, the reader will remember that the line which divided loads passed through the 17-pound weight in such a manner as to leave 4

pounds of this weight supported at the B end and 13 pounds supported at the A end. The maximum bending moment is therefore located at this weight. To calculate this bending moment we may start at either end of the beam, multiply every weight by its distance from the end and proceed as far as the dividing line. Adding all of these products together gives the bending moment at the dividing line where it is maximum. As a proof we may start from the other end and calculate the bending moment in the same manner and the two results should agree.

Starting from the end A (Fig. 33) we first come to the 11-pound weight at a distance of 2 feet and then a 13-pound weight at a distance of 7 feet. This 13 pounds is part of the 17-pound weight, but it must be remembered that 4 pounds of this 17-pound weight belongs to B and must not be considered when we are calculating the bending moment by multiplying the weights supported at A by their distance from A. Hence our first product is 22 (11×2) and our second is 91 (13×7). Adding these two together gives us 113 ($91+22=113$), which is the maximum bending moment of the beam in pounds-feet.

Starting from the end B we first come to a 21-pound weight at a distance of 4 feet, and next to the 4 pounds (part of the 17-pound weight) at a distance of 7 feet. The bending moment calculated from this is $(21 \times 4)+(4 \times 7)=84+28=112$, which agrees practicaly with that calculated by starting from the end A. If we had not neglected some fractions the results would have been identical.

In all calculations which we have made, with but a single exception, which we will now note, any distributed weight may, for the purpose of calculation, be considered as if entirely collected at its center of gravity, is where the dividing line cuts it into two portions. In this case each portion is supported at a single point and that point is the cener of gravity of that distributd weight. The exception we referred to applies to minute depressions in the metal, so as to be supported by a different end of the beam, but a single operation; that is, the final operation, and each portion must be considered as just described, in calculating having a center of gravity of its own for the maximum bending moment of a beam the purpose of calculating the bending moment. Such a division is not necessary in calculating the distribution of the weight between the supports. In fact, it is not until after this calculation has been made that the position of the dividing line is known, and consequenly any division of weight depending upon the position of the dividing line is impossible until after this calculation has been made.

The shearing strain in a beam supported at both ends is maximum at the point of support which sustains the largest portion of the total load, and is equal to the load supported there. Thus, in Fig. 33 the total shearing strain at A is 24 pounds and at B 25 pounds. By dividing by the sectional area of the beam in square inches the shearing strain per square inch may be arrived at.

The above are the general methods for calculating the maximum bending moment under any conditions, but special rules often expedite the calculations, and we will now consider some of these special cases.

The most usual case is what is known as the symmetrical load. This may consist of any or all of the following three: First, a load placed at the center of the beam; second, a load uniformly distributed over the entire length of the beam, and, third, pairs of equal loads so placed that one is the same distance from one end of the beam as the other weight is

from the other end. The dividing line and consequently the maximum bending moment of a symmetrical load is the center half way between supports, dividing any weight which may be located there into two even portions. The maximum bending moment may be calculated by taking one-half of the beam, multiplying every weight on that half and the half of the center weight, if there be one, by their distances from their support.

Another common case is where but a single weight is supported by the beam. The maximum bending moment is located under the weight and is equal to the weight multiplied by the product of its distances from both supports and divided by the total distance between supports. This may be easily proven by rules previously given.

Many manufacturers publish tables showing the sustaining power of beams. These generally show the weight which different beams will support for different spans when the load is distributed uniformly over the whole length of the beam. The principles given here, for which we are indebted to *Motive Power,* will show how much more or less a beam will sustain when the load is distributed in any manner whatever.

As said before, the built up beam is made of a plate and angles and are calculated to stand the strain but are greatly strengthened by connecting the outer legs of the flange angles by means of a "cover" plate. These cover plates answer as additional flange material and riveted to the angles at regular intervals and it is best to arrange the rivets so that none need be countersunk to allow the placing of braces or stiffeners.

These cross the web at right angles to the angles and are driven in tight under the flanges.

Cover plates are put on after the angles are riveted to the webs.

The bending of an angle to conform to the flange angle and fit down on the plate of a girder is called "crimping."

Fig. 35 gives location of rivet from the corner of the bend, and angles used in crimped stiffeners should be ordered of a length equal to the depth of girder, to allow for crimping plus a little excess on each end for fitting.

All material which is to be faced at the ends should be ordered about ¼" longer for each facing. This occurs in most end posts, all top chord sections, most floor beams and stringers.

All stiffeners on girders, and other angles which are to be fitted in between flange angles should be ordered at least ⅛" long at each end for fitting.

Pieces fitted in behind these stiffeners are called "fillers."

Rolled iron beams are so much used in modern building that I am emboldened to draw attention to a few little points in connection with them and with construction attached to them, which are not always thoroughly understood or borne in mind by workmen.

First, as regards the strength of a rolled-iron beam. I have referred in a former article to tables showing the strength of rolled iron, which have been published by various firms of manufacturing engineers. Such tables are, as I have already stated, very handy for reference. Yet it will be as well, perhaps, to explain a simple method of calculating the strength of an ordinary rolled-iron beam, if only to show that there is nothing very complicated about such calculations, as too many people are apt to suppose. The usual rule is to take the sectional area of the bottom flange in square inches; multiply it by the total depth of the beam in inches; multiply this again by seven and divide the result by the span of the beam in feet. The result of this gives the number of tons required to break the beam

if placed upon it in the middle of its span. If the weight is to be evenly distributed over the whole beam, instead of being concentrated in the middle, twice as many tons will be required to break it—that is to say, that in multiplying we should use the number fourteen instead of seven. In calculating the sectional area of the bottom flange this is taken up to where the straight part of the web commences, the required sectional area being the lower portion shaded in Fig. 36. Rather a troublesome job, it may be thought, to calculate the number of square inches in such an irregular form with any degree of nicety. But a very simple rule, which ought to be more generally known, may come to our assistance here. In rolled-iron beams or bars of any uniform section three times the number of pounds per foot run, divided by ten, will give the area of the whole section in square inches. Referring to Fig. 36, we can easily measure the sectional area of the straight part of the web, which is unshaded, and deducting this from the whole sectional area, found by the preceding rule, the remainder is the united areas of the two flanges shaded in the diagram. These being usually equal, we have only to take half the result of our calculation for the required sectional area of the bottom flange.

The permanent load upon a rolled-iron beam should not exceed one-fourth of the weight required to break it, and it should not be tested to more than one-third of it. If any specimen of the iron has been broken, this gives us an opportunity to judge of its quality. The fibers of the metal should be long and silky, and the grain should not be coarse.

For constructural purposes it is often necessary to make holes in iron beams for bolts to pass through. The holes should be drilled, for if punched their sizes are apt to be unequal, besides which the metal immediately surrounding a punched hole is always more or less weakened. Much depends upon the positions of the holes, if the strength of the beam is to be economized. Remember that when a beam is supported at the ends and loaded from above it is subjected to two kinds of strains—one tends to stretch or tear asunder the lower part of the beam and the other tends to compress or crush the upper part. About midway between the top and bottom of the beam is what engineers call the neutral line, where the pulling and pushing strains are supposed to balance one another; and at this part the metal remains practically unaltered in form, however much the beam may bend, so long as it does not break. It is evident that the metal at the top of the beam is most severely compressed, while that at the bottom is most severely stretched; and the safest position for holes is at or near the middle, where they will least detract from the strength. Holes drilled in the lower part tend to widen by stretching, and obviously weaken the beam by reducing the resistance to tension; but holes drilled in the upper part tend to become reduced in size by compression, and they do not, therefore, weaken the beam, provided that they are completely filled by the bodies of iron bolts, which resist compression, preventing the holes from being reduced in size. Hence, if we have any choice

Rivets in Crimped Angles.

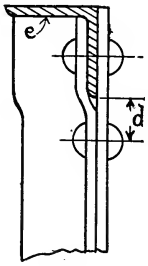


Fig. 35

When angles are "crimped" to fix the chord angles on a girder or elsewhere, the distance d should be $1\frac{1}{4}$ plus twice the thickness of angle e.

in arranging the positions of holes in iron beams we should place them in the middle or upper part by preference. In calculating the strength of riveted girders, engineers always deduct the space traversed by rivet holes in the bottom flange, and this rule should be followed in respect to any bolt holes in rolled iron beams.

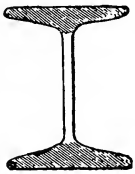


Fig. 36

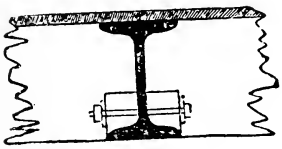
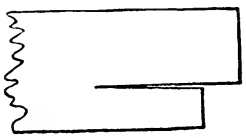


Fig. 37

In ordinary wood-joisted floors, divided into spans by rolled-iron beams, there are more ways than one of connecting the joists to the iron beams. Many persons adopt the method shown in Fig. 37.

Here a plate rests upon each bottom flange, being either bolted down to the flange, or, for better economy in drilling and bolting, bolted right through the lower part of the web. This drilling through the lower part of the beam is objectionable, as already explained. Besides this the joists are notched out for the plates, which weakens them terribly; indeed, it may be said that if an 11-in. joist is notched out 4 in. on its lower end, its strength is almost reduced to that of a 7-in. joist, so serious is the result of cutting away the bottom fibers of the wood, which resist the stretching strain. Under such circumstances the strain upon the joists is very liable to produce a split like that shown in Fig. 38.

Fig. 38



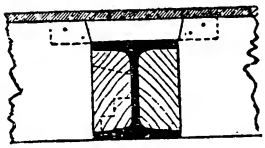


Fig. 39

A better method of attaching joists to an iron beam is by bolting a piece of timber against each side of the beam, for the entire depth between the flanges, and by tenoning the joists into these timbers on both sides, as shown on the left side of the diagram in Fig. 39. But there is considerable labor involved in cutting the tenons and mortises, besides which there is sometimes a practical difficulty in getting the joists into position. On the right side of the diagram the ends of the joists are simply cut to fit in between the flanges, each joist taking its bearing upon the bottom flange. By this means the joists obtain a more solid and even bearing (for the tenons may shrink unequally, throwing all the pressure upon one shoulder), and blocks of wood, cut to the proper length, are bolted in between the ends of the joists to prevent them from moving laterally.

Sometimes it is desirable for joists

inserted against the sides of an iron beam to act as ties. This is especially the case when the beam is used as a shop breastsummer, the joists being required to assist in holding in the front wall of the building. This may be done by means of a strap-bolt attached to about every second or third joist by means of small bolts or screws, as shown in Fig. 40.

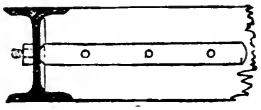


Fig. 40

The form of such a belt, which should be all forged in one piece, will probably be understood from Fig. 41, where the bolt is seen in plan.

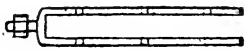


Fig. 41

Another way of securing a tie is by means of L-straps, one arm of the L being bolted against the joist and the other against the web of the iron beam, or against the timber bolted to the web.

In cases like Fig. 37 and Fig. 39 the ceiling beneath and the floor above are easily managed. First, as regards the ceiling. Whether the under sides of the joists are flush with the bottom of the beam, or drop below it, all we need do is to fix the laths diagonally where they have to cross the beam. Then, as regards the floor. If the tops of the joists are flush with the top of the beam, as in Fig. 37, a floor board of sufficient breadth will lie upon the top flange of the beam having each of its sides nailed or screwed into the ends of the joists; but if the tops of the joists are above the top of the beam, as in Fig. 39, fillets of wood are placed upon the top flange to receive the floor flange by means of screws or are nailed sideways against the joists, as shown in Fig. 39.

CHAPTER VII.

COLUMNS AND LACING

The subject of the interior columns for steel buildings forms one of the most important branches of modern building design, and greater variations are probably to be found here than in any other of the vital features of steel construction. The subject of fireproof construction is steadily growing in importance. The need of fireproof buildings in the business centers of our great cities has been only too well demonstrated to us by the recent fires at Baltimore and San Francisco and the large number of smaller conflagrations which have taken place throughout the country during past years.

The substitution of steel for iron in the composition of columns may be cited as one of those radical changes which have taken place in the last few years and which show unmistakably the tendency of the times to depart from such forms of construction as involve any large degree of risk or uncertainty. The adoption of the steel column has brought with it a large number of forms of column construction, each having its own good points and special applications. The more prominent forms of steel columns, as used in American building practice, include channels connected by plates or lattice, plates and angles in various combinations and "Z" bar columns. Besides these types and the considerable number of variations found in each there are a number of patented forms which have been used less extensively. In Fig. 42 the commonest forms of channel columns are shown.

For light members, as in upper stories, the channels are often placed back to back or flange to flange, and connected by means of tie-plates and lattice bars. The former method of placing the channels back to back is somewhat easier as regards the riveting. The third form shown, with cover plates either single or double, is one of the most common column sections employed. The fourth form shows a combination of two channels and an I-beam. A variation of this section is sometimes made by substituting a plate and four angles in place of the I-beam, or one or more plates and two angles for the channel sections, as shown in designs 5, 6 and 7. Typical forms of plate and angle columns are shown in Fig. 43.

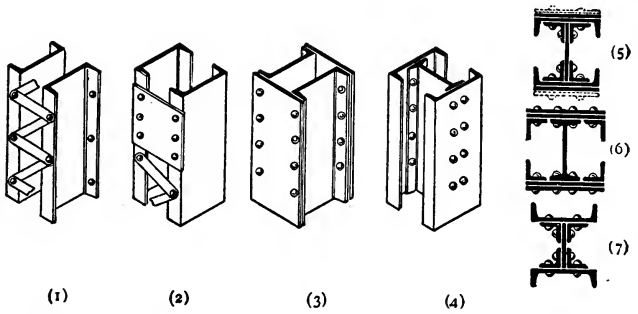
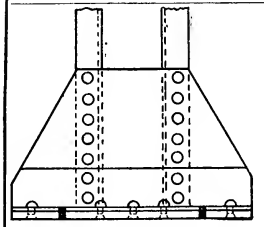
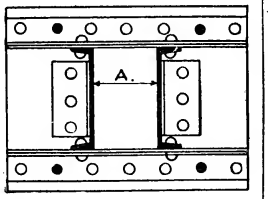
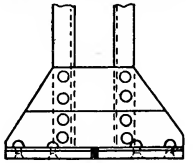


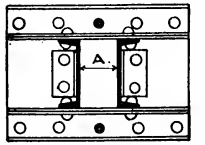
Fig. 42

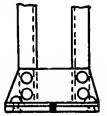
STANDARD BASES FOR CHANNEL COLUMNS

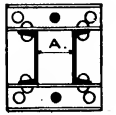












15″ column for 227 tons
13″ column for 214 tons
12″ column for 182 tons

15″ column for 137 tons
13 column for 130 tons
10 column for 136 tons
9 column for 104 tons
8 column for 91 tons
7 column for 83 tons
6 column for 66 tons

12″ column for 83 tons
10 column for 69 tons
9 column for 57½ tons
8 column for 45 tons
7 column for 39 tons
6 column for 32 tons

Bearings on Foundations 500 lbs. per sq. in.

Submitted by L. A. Starrett

Dist. A	Column	Safe Load	Size of Base	Size of Gussets
9 ″	15″	227	28″x1½″x2′– 8″	21″x½″x2′– 8″
“	“	137	28 x1 x1′– 8	12 x⅝ x1′– 8
8“	13	214	24 x1½ x3′– 0	21 x½ x3′– 0
“	“	130	24 x1 x1′–10	12 x⅝ x1′–10
7½	12	182	21 x1½ x2′–11	21 x½ x2′–11
“	“	83	21 x1 x1′– 4	.....
6“	10	136	20 x1 x2′– 3	12 x⅜ x2′– 3
“	“	69	20 x¾ x1′– 2	.....
5½	9	104	18 x1 x1′–11	12 x⅜ x1′–11
5¾	“	57½	18 x⅔ x1′– 1	.....
5½	8	91	16 x1 x1′–11	12 x⅜ x1′–11
5¾	“	45	16 x¾ x1′–	.....
5½	7	83	15 x1 x1′–10	12 x⅜ x1′–10
“	“	39	15 x¾ x0′–11	.....
“	“	66	14 x1 x1′– 7	12 x⅜ x1′– 7
5¾	“	32	12 x¾ x0′–11″	.....

Weight of Plates	Size of Angles		Weight of Angles	Weight of Rivet Hds.	Total Weight
571	6″x4″x½″x2′– 8″	6″x6″x½″x1′– 0″	126	11	708
210	6 x4 x⅝ x1′– 8	6 x4 x⅝ x1′– 0	66	7	283
581	6 x4 x½ x3′– 0	6 x6 x½ x0′–10	130	11	722
206	6 x4 x⅝ x1′–10	6 x4 x⅝ x0′–10	66	7	279
527	6 x4 x½ x2′–11	6 x6 x½ x0′– 9½	126	11	658
95	6 x4 x⅝ x1′– 4	6 x3½x⅝ x0′– 9½	51	3	149
222	6 x4 x⅝ x2′– 3	6 x6 x7/16x0′– 7½	77	7	306
60	6 x4 x⅝ x1′– 2	6 x3½x⅝ x0′– 7½	43	3	106
176	6 x3½x⅝ x1′–11	6 x3½x⅝ x0′– 7	59	7	242
50	6 x3½x⅝ x1′– 1	.....	25	3	78
163	6 x3½x⅝ x1′–11	.....	45	6	214
41	6 x3½x⅝ x1′–11	.....	23	3	67
150	6 x3½x⅝ x1′–10	.....	43	6	199
35	6 x3½x⅝ x0′–11	.....	21	3	59
124	6 x3½x⅝ x1′– 7	.....	37	6	167
28	6 x3½x⅝ x0′–11	.....	21	3	52

Supplement, The Industrial Magazine, June, 1907.

The simplest combination is that made in the form of a beam. One or more webs may be used, or fillers between the angles, as shown by the dotted lines, but any additional material is placed to better advantage if used in the form of cover-plates, riveted to the outer legs of the angles. The I section

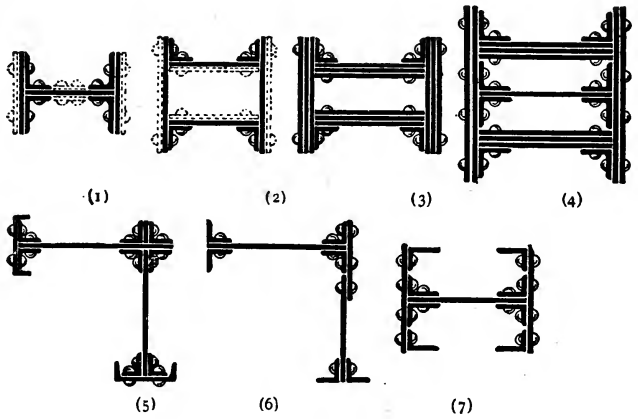


Fig 43.

of plates and angles is extensively used in cases where the loads are sufficiently light to permit of it. The box form of plates and angles, shown on the second type in the illustration, is one of the most ordinary as well as commendable forms in common use. This section may be readily strengthened by using

the St. Paul building in New York City, and the Masonic Temple in Chicago.

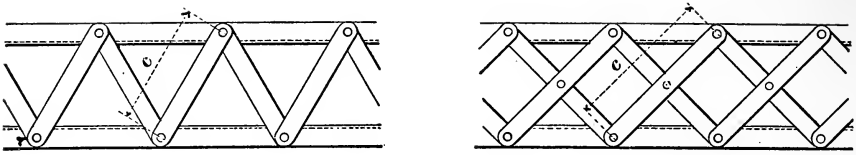
Z-bar columns and variations are shown in Fig. 44. The ordinary section is as in form 1, this being made in the standard sizes of 6-inch, 8-inch, 10-inch and 12-inch columns, by using

Fig. 44

additional web-plates, cover-plates or filler-plates, as illustrated by the dotted lines, or by section 3. Columns of this form have been used in a great many notable high buildings; as for example,

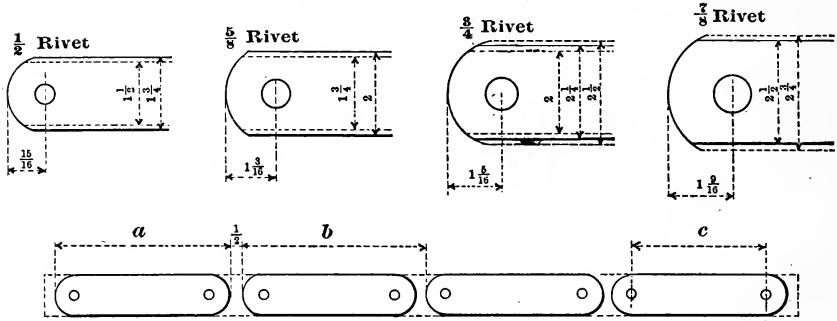
3-inch, 4-inch, 5-inch and 6-inch Z's respectively. When the load can be safely carried without the aid of cover-plates, and if the size of the column does not become too large for its relative position in the building, it is more economical to use the simple section, but when additional area is required,

one or more cover-plates may be added as shown by the dotted lines. Form 2, known as the "standard dimensions" Z-bar column, was designed to allow of the outside dimensions of such columns



Maximum Distance c for given thickness of bar.

SINGLE LACING $t = \frac{c}{40}$		DOUBLE LACING $t = \frac{c}{60}$	
THICK. t	DISTANCE c	DISTANCE c	THICK. t
$\frac{1}{4}$	0 - 10	1 - 3	$\frac{1}{4}$
$\frac{5}{16}$	1 - $0\frac{1}{2}$	1 - $6\frac{3}{4}$	$\frac{5}{16}$
$\frac{3}{8}$	1 - 3	1 - $10\frac{1}{2}$	$\frac{3}{8}$
$\frac{7}{16}$	1 - $5\frac{1}{2}$	2 - $2\frac{1}{4}$	$\frac{7}{16}$
$\frac{1}{2}$	1 - 8	2 - 6	$\frac{1}{2}$
$\frac{9}{16}$	1 - $10\frac{1}{2}$	2 - $9\frac{3}{4}$	$\frac{9}{16}$
$\frac{5}{8}$	2 - 1	3 - $1\frac{1}{2}$	$\frac{5}{8}$



Distance to be added to C. C. length c.

WIDTH OF BAR	FINISHED LENGTH a				ORDERED LENGTH b				WIDTH OF BAR
	DIAM. OF RIVET				DIAM. OF RIVET				
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	
$1\frac{1}{2}$	$1\frac{7}{8}$				$2\frac{3}{8}$				$1\frac{1}{2}$
$1\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{3}{8}$			$2\frac{3}{8}$	$2\frac{7}{8}$			$1\frac{3}{4}$
2		$2\frac{3}{8}$	$2\frac{5}{8}$			$2\frac{7}{8}$	$3\frac{1}{8}$		2
$2\frac{1}{4}$			$2\frac{5}{8}$				$3\frac{1}{8}$		$2\frac{1}{4}$
$2\frac{1}{2}$			$2\frac{5}{8}$	$3\frac{1}{8}$			$3\frac{1}{8}$	$3\frac{5}{8}$	$2\frac{1}{2}$
$2\frac{3}{4}$				$3\frac{1}{8}$				$3\frac{5}{8}$	$2\frac{3}{4}$

Fig. 45—As recommended by Am. Bridge Co.

being kept standard for all stories; irrespective of the size or thickness of Z's required, but on account of the tie-plates required in either one or both directions increasing the shop costs, and decreasing the efficiency of the column under eccentric loading, the form has never come into extensive use. Sections 3 and 4 show heavy columns combining Z's with plates and channels. Section 5 shows a combination of two Z-bars with one I-beam.

The foregoing examples will serve to show the great number of forms offered the designer from which a selection may be made; nearly all of them are to be found in prominent examples of building construction. The relative advantages of these standard sections are obviously of importance in influencing a choice, but that any particular type can be selected as the best for universal application is manifestly impossible; selection must be made to fit the particular requirements and in keeping with the ideas and opinions of the designer.

A built up column in use outside presents many crevices for moisture to collect, especially the type with base and side plates and lattice bars.

These side plates extend only a short distance leaving a pocket for the accumulation of dirt and water.

To overcome this the space may be filled with cement and smoothed off, higher at the center, to shed the rain and snow.

LACING.

The illustrations shows the two forms of lacing commonly used, though the one to the right is often called lattice work, Fig. 45.

It will be seen that for a given size of rivet that certain widths of bars may be used, the size of the rivet is determined by rules mentioned under head of Rivets, Chapter II.

The single lacing is usually set at an angle of 60° with the channel or I-beam, while the double lacing is at 45°.

A pair of dividers should be used in this work so that the spacing will be shown evenly divided.

CHAPTER VIII.

TRUSSES.

A truss is a simple framed structure composed of straight members so connected as to act as a rigid body. It is constructed to resist the action of force by transferring it from one position to another. While the truss as a whole resists the effect of the external forces acting on it in much the same manner as a solid beam resists shear and bending moments, each individual member of the truss is subjected only to direct or compressive stress in the direction of its length. In order to bring this about, the external forces must be applied at the joints of the truss, through which they act upon the structure as a whole.

framed structure so designed that the reactions from the superimposed static loads are vertical.

A symmetrical truss is a truss so designed that if it could be folded at the center upon itself in such manner that the two ends would come together, all corresponding members in the two halves of the truss would coincide. Nearly all trusses are symmetrical.

A simple truss is a truss whose ends simply rest on the points of support without being rigidly fixed to them. A cantilever truss is one which extends beyond its supports.

The theoretical span of a simple truss is the distance between the centres of

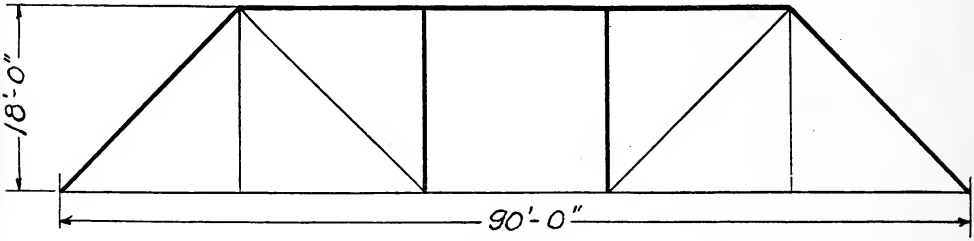


Fig. 46. Diagram of Platt Truss

The simplest truss is a triangle, and any truss is merely a combination of connected triangles. As the triangle cannot change its form so long as the length of each of its sides remains the same, it is the primary and essential element of the truss.

The external forces are the loads, including the weight of the structure itself, and the supporting forces, or reactions. A load is any force which tends to distort the structure or change its form.

In bridge engineering a truss is any

its supports. The truss is divided into a certain number of parts or sections, usually of equal lengths, called panels. The panel lengths are the horizontal distances between the joints of the loaded chord.

When mentioned without reference to their positions in the truss, those members which resist compressive stresses are called struts, or compression members, and those which resist tensile stresses are called ties, or tension members. Each individual member, however, is usually mentioned with ref-

erence to its position in the structure. When the diagonal members of a truss are compression members, they are called braces; the counters are called counterbraces.

A compression member can resist a certain amount of tension also; but a member designed to resist tension only is not usually capable of resisting compression. When it is desired that a tension member shall resist a small amount of compression also, the form of the member must usually be changed.

When the loads on a simple truss are downwards, as is nearly always the case, the upper chord is always in compression and the lower chord always in tension. In the web system the struts and ties alternate.

through bridge is represented in the figure.

The essential difference between a Howe truss and a Pratt truss is that in the former all vertical members are ties (tension members), and all diagonal members are struts (compression members) while in the latter the opposite is the case. The method of constructing a diagram of stresses is practically the same for both trusses.

The duties of diagonal and vertical members in the Howe truss are the reverse of what they are in the Pratt truss. The maximum stress in any vertical web member of a Howe truss, and in the diagonal meeting it at the upper chord, occur when the joint at the foot of the vertical member and all

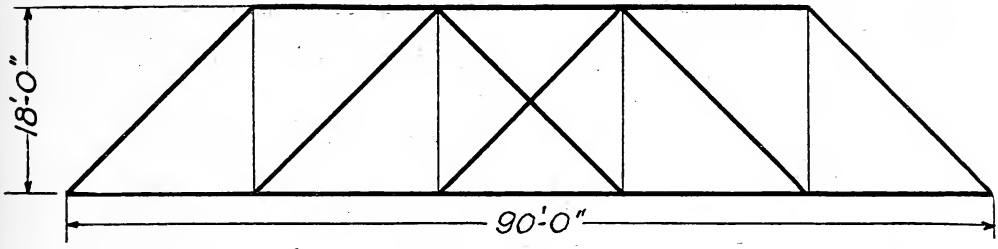


Fig. 47. Diagram of Howe Truss

The favorite style of truss now used for moderate spans is what is commonly known as the Pratt truss which was patented in 1844 by Thos. W. and Caleb Pratt. As a metal structure it possesses advantages over all other forms of trusses

THE HOWE TRUSS.

The Howe truss was devised by William Howe, in 1840. It is an excellent form and is much used in this country in localities where timber is cheap. For trusses constructed entirely of metal, however, it is not as economical as the Pratt truss.

In the modern types of the Howe truss the lower chord is usually constructed of metal. Such a truss for a the joints at the right are loaded, the others being unloaded.

PRATT TRUSS.

The vertical web members of the Pratt truss are struts while the diagonal members are ties.

In a Pratt truss, the maximum stress will occur in the diagonal web member in any panel when all joints at the right of the panel are fully loaded and the joints at the left of it are not loaded. This condition will also give the maximum stress (of opposite character) in the vertical member which meets the diagonal in the unloaded chord.

CHAPTER IX

TITLE PAGE AND COVER

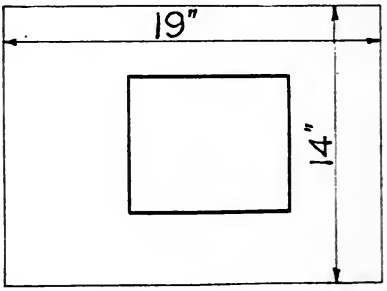
THE TITLE PAGE.

When the drawings are all completed, a title page should be made, to be placed over the other plates when they are bound. A very convenient way to bind the plates is to insert them in a cover of heavy manilla paper and fasten them together at the left by means of two or three paper fasteners. Inside the cover the title page should appear first, followed by the other plates in order, beginning with Plate I at the top.

The accompanying illustration shows about the simplest form to be made and one which looks very well. The border line of the title page shown may be set in ½", making the space 12 x 16, instead of 13 x 17, or it may be drawn in still more as shown on the opposite cut (about 6¼ x 9"). In any case, the vertical center line of the lettering is 9" from the right edge of the paper when cut to 14 x 19.

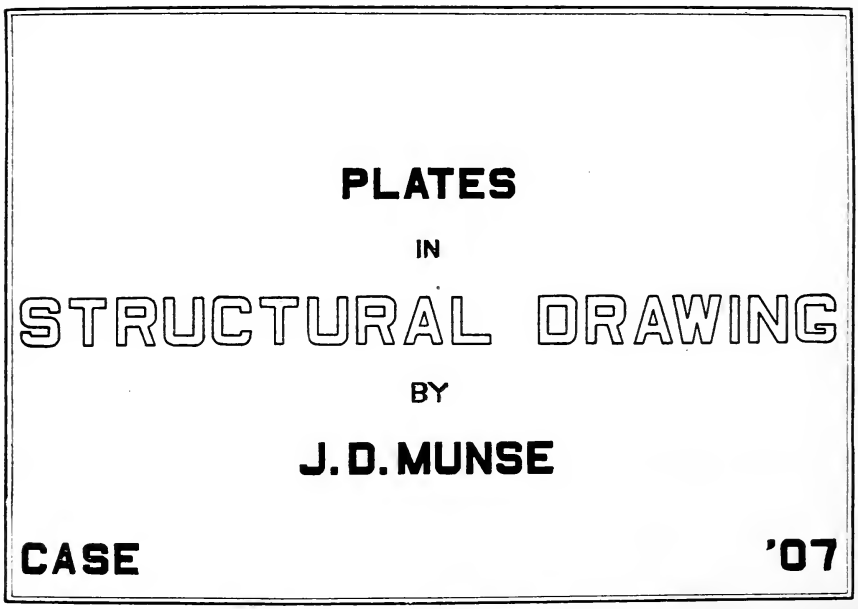
The top line of the letters in "STRUCTURAL DRAWING" is 5" from the top border line when the space is 12 x 16; this places the row of letters a little above the center.

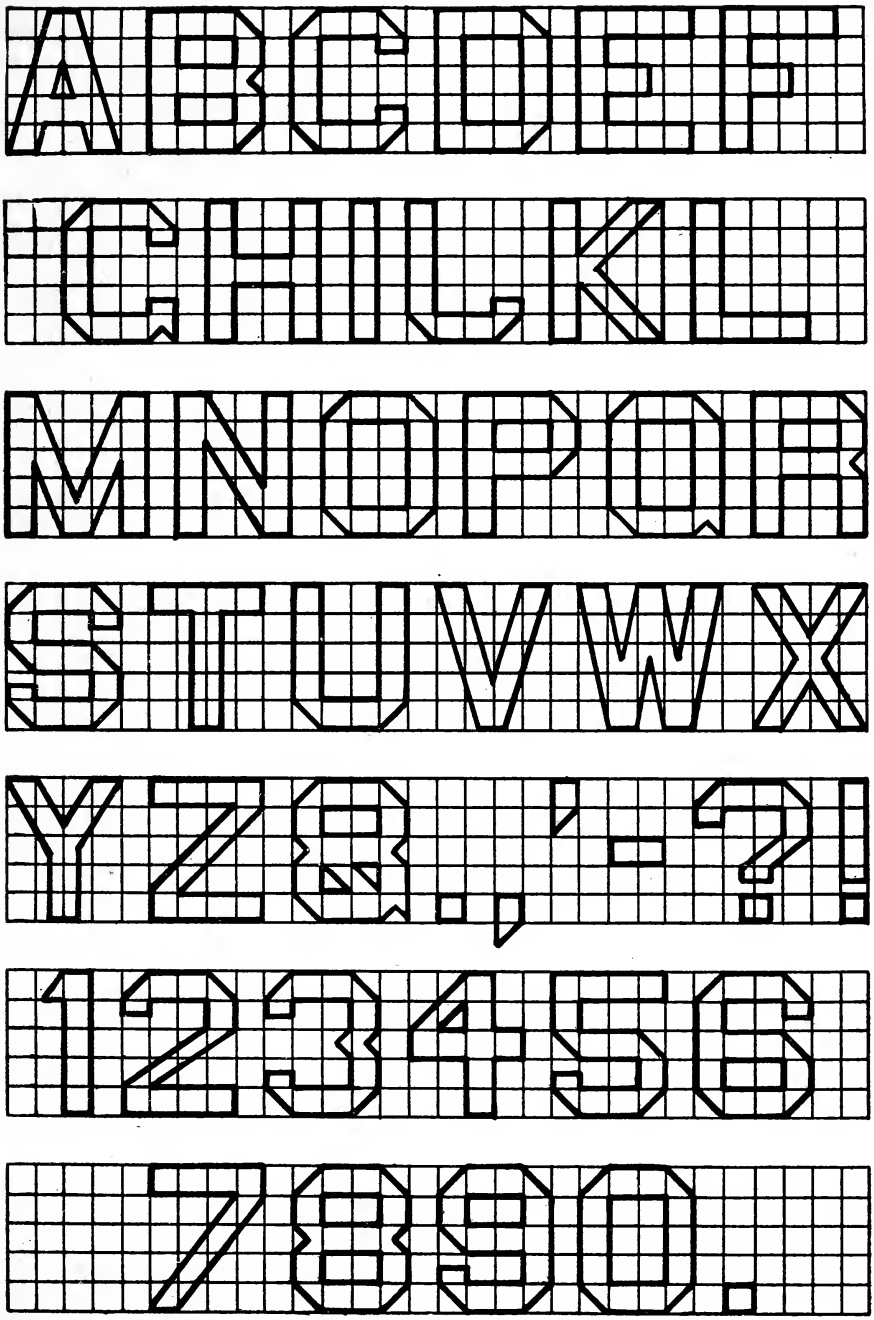
The blocks for the letters (see next page) are 3-16" square, and allowing three between "Structural" and "Drawing" and none between "A" and "W" and one between each letter we will need 82 spaces or blocks, or 15⅜", leaving 5-16" at each end. The words "PLATES," "Students' Name" and



"School" should be built on ⅛" blocks. "IN" and "BY" on 1-16" blocks. Always use the dividers to step off the blocks, and be careful to have them square.

It will be noted that the round corners of the letters are put in from centers either on the corners of blocks or at their centers. Ink in the outline of the letter before filling black.





Through an error the letter "J" in above drawing became reversed.

a b c d e f g h i j k l m n o p q r s t u v w x y z 1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z I II III IV V VI VII VIII IX X L

The size of this Drawing is to be 14"x18" Outside Dimensions and 13"x17" inside the Border Line Put everything on the plate Exactly as shown except the Figures which indicate the height of the Letters. These are to be Left off &c &c To lay out the plate begin at the left hand border and Measure off $\frac{3}{8}$" of an Inch for a margin. Then Divide the Plate Vertically into spaces 1" wide Put two Lines of letters in each One inch space, the lines to be laid out as follows – The The Bottom of the letters in the lower line of each 1" Space must Coincide with the Division line of the space and the bottom of the Upper line in each one inch space is to be placed $\frac{1}{2}$" above the Division line of the Space. Both Horizontal and Diagonal Guide lines must be drawn before the letters Are put in. The diagonals have a slope of 2 to 1 as Shown. This gives the slope of the stems. The Ellipses Which form the bottoms of the small Letters Have a slope of 45°. The body of the letter should be $\frac{3}{5}$ of the whole height and the stems of the letters g j p q should extend two fifths of the whole height Below the line. In the first two lines On this plate the Arrows Show the Direction of the strokes. The appearance of a Drawing is often spoiled by Careless lettering. There are three Rules Which it is Necessary to observe in order to letter well. The First rule is to select a simple style of Letter and Always stick to it. A practical letter is one that Can be rapidly and easily Made Freehand. The second rule is Practice. The third rule is more Practice. The type of letter shown on this Plate is recommended as one of the most practical for Ordinary mechanical Drawings its principal advantage Being the speed with which the Letters can be made. Care should be taken to Keep the spacing even, for if the slant is Uniform and the Spacing good the work with look Right even if the Individual letters are not all well made. This style of lettering looks the best When the letters are kept rather Narrow in proportion to the Height and the spacing is Close. The size of the letters here is $\frac{1}{8}$" for the Body, and the stems extend $\frac{1}{16}$" above and below The line. The Capitals are all $\frac{3}{16}$" High. A complete Discussion and description of this Style can be Found in "Reinhardts Lettering for Draftsmen, Engineers and Students", Published by D Van Nostrand Co, New York. Price one dollar. This plate must be penciled in and approved by the Instructor before any ink is put on it. The title, name and date is to be placed in the corner as shown, in a Rectangle $1\frac{1}{2}$"x3" in size. The best pen for this work is a Gillotts 303 which has been well broken in, that is it ought to have been used enough to remove the sharp point and become Flexible.

Plate I
Soph. Mechanical Drawing
Name
Date

CHAPTER X

DRAFTING ROOM PRACTICE

If the student, having completed the plates of this course, should be fortunate enough to secure a position in a drafting room, it will be partly due to neatness of work on the drawings, hence each young man is urged to practice unceasingly on free hand lettering and figuring, using guide lines ⅛ in. apart.

A good style is shown on a previous page and as mentioned on page 28, it is expected on all drawings of this course.

When a young man enters a drafting room, he is either put to blue printing, tracing or lettering lists and tables, depending on his previous experience.

The tracing work is the copying of drawings on a prepared cloth, which is transparent, one surface dull, the other glossy. The dull side is used more often than the other, because it takes the ink more readily and does not show corrections as easily as the glossy surface. After the drawing is trued up to the tee square the cloth is placed over it and the edges tacked down. Either surface of the cloth will take ink far better after being rubbed with a powder of chalk or potter's clay, this removes the slight coating of oil apparent on new cloth. All curved lines should be drawn first, then the horizontal, then the vertical, but care should be exercised to join the straight with the curved lines. The lettering should be done neatly and directly over that on the drawing, unless otherwise instructed.

Sometimes the list of pieces on the job is placed on the drawing and known as the "Bill of Material," but more generally it is on a separate sheet.

Several forms are here given of "Bills of Material," "Shipping Lists," "Pin Tables," etc., etc., which are printed on white paper or blue print and filled in by the draftsman. The student should study these so as to be familiar with them, though they differ much in all shops and factories.

FORM NO. 5

KING BRIDGE CO., CLEVELAND, OHIO

CONTRACT 125-06 SHEET NO. 1

BILL OF MATERIAL

DESCRIPTION 125' SPAN. MADE BY B

FOR	NO. SHEET	NO. PIECES	KIND	SIZE	LENGTH	CUT FROM		ORDERED OF	REMARKS
						No. PIECES	LENGTH		
U'-U²	1	6	S.S.	4X3X3/8	25'-0"	6	25'-0½	CAR.	

L of C.

Form No 4.

KING BRIDGE CO.,

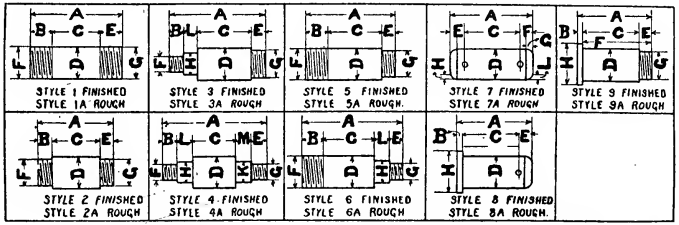
CLEVELAND, OHIO.

CONTRACT NO. .....

SHEET NO. .....

QUALITY MATERIAL .....

FOR .....



To be inspected and accepted before shipment.

Pins to be coated with white lead and tallow.

Ship .....

Drawing Finished .....

Approved.....19.....

By.....

SHIPPING MARK	NUMBER REQUIRED	STYLE NO.	MATERIAL LENGTH A	MATERIAL DIAM. D	GRIP C	B	E	F	G	H	K	L	M			SIZE OF COTTER	CUT FROM	ORDERED OF	STYLE OF NUTS	

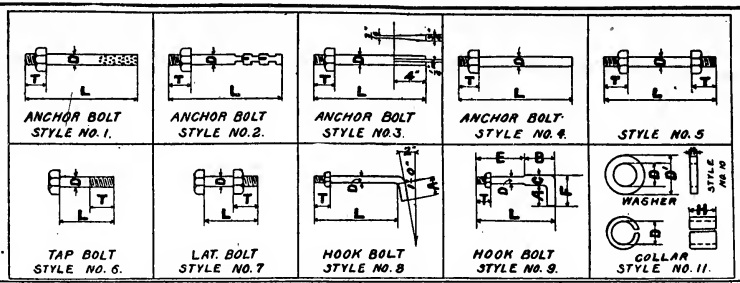
PILOT NUTS. DRIVING NUTS.

Sketch sheet for pins to be filled out according to the job

FORM No. 12.

KING BRIDGE CO.,
CLEVELAND, OHIO.

CONTRACT NO. 144 of 1905
SHEET NO. 6 of 7
QUALITY MATERIAL
FOR Highway Bridge over Big Black-Madison Co. Miss.


ANCHOR BOLT STYLE NO. 1.
ANCHOR BOLT STYLE NO. 2.
ANCHOR BOLT STYLE NO. 3.
ANCHOR BOLT STYLE NO. 4.
STYLE NO. 5
TAP BOLT STYLE NO. 6.
LAT. BOLT STYLE NO. 7
HOOK BOLT STYLE NO. 8
HOOK BOLT STYLE NO. 9.
WASHER
STYLE NO. 10
COLLAR STYLE NO. 11.

To be inspected and accepted before shipment.

Ship July 20, 1905.
Drawing Finished 4/19/05.
Approved ..... 19.....
By .....

SHIPPING MARK	NUMBER REQUIRED	STYLE No.	MATERIAL LENGTH L	MATERIAL DIAM. D	A	B	C	D'	E	F	H	T	CUT FROM	ORDERED OF	STYLE OF NUTS	
L0	4	11		2 1/2"							6 3/8"					
L1	8	"		"							1 3/8" 1 1/2"					
L2	4	"		2 1/2"							1 1/2"					
"	4	"		2 1/2"							2 3/8"					
L3	4	"		"							1 1/4"					
"	4	"		"							2 3/8"					
U1	4	"		"							4 5/8"					
U2	4	"		2 1/4"							5 3/4"					
U3	8	"		2"							2 5/8"					
L0	4	6	2 1/2"	1 1/2"		1/2"						3/4"				

Sketch sheet for anchor bolts and collars partly filled

Form No 10

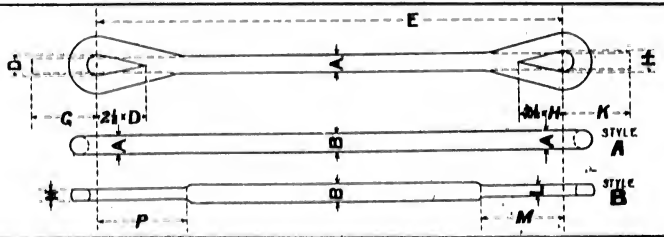
KING BRIDGE CO.,
CLEVELAND, OHIO.

CONTRACT NO.

SHEET NO.

QUALITY MATERIAL

FOR .....



To be inspected and accepted before shipment.
Dope pin holes with white lead and tallow.
Paint
Will paint be shipped? YES. NO.
Ship
Drawing Finished
Approved 19
By

SHIPPING MARK	NUMBER REQUIRED	STYLE OF ROD	MATERIAL				LENGTH C. TO C. OF HOLES	LOOP								LOOP			
			SIZE OF SQUARE A Width	SIZE OF SQUARE B Thick	ORDERED LENGTH	ORDERED OF	E	D DIAM. OF EYE	D DIAM. OF PIN HOLE	A THICK	G ADD	P Length of Flat End	N Thickness of Flat End	H DIAM. OF EYE	H DIAM. OF PIN HOLE	A THICK	K ADD	M Length of Flat End	L Thickness of Flat End
U2-L8	8	SG	1	1	16'-8"	CARNEGIE	14'-0"	2⅞	3"	1	16"	8"	⅞	2⅞	3	1	16	—	—

Sketch-Sheet for loop rods, partly filled. Note that each piece has a letter.

FORM No 13.

KING BRIDGE CO., CLEVELAND, OHIO.

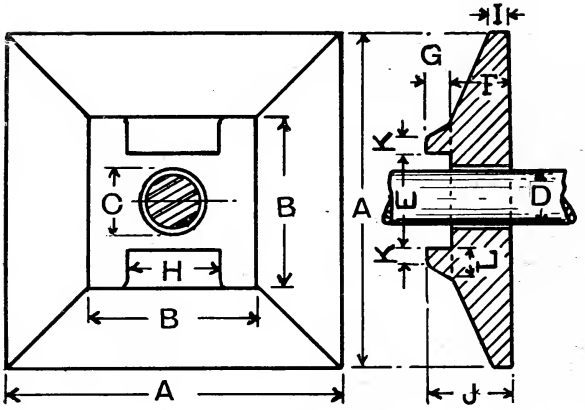
SHIPPING LIST. Ship July 1-06 No. 125 of 1906

125 0" LENGTH 18'-0" R'D'V 5 PANELS AT 25'-0"

DESCRIPTION. PIN. CON. THRO. SPAN.

SHEET No.	No. of PCS.	CHECK	NAME AND MARK	SECTION	WEIGHT	CAR NUMBER

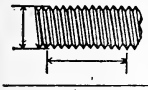
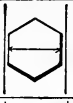
Foundation Anchor Plates



FOUNDATION ANCHOR PLATES.

D	A	B	C	E	F	G	H	I	J	K	L
$1\frac{1}{8}$	$6\frac{3}{4}$	$3\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{15}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$	$1\frac{11}{16}$	$\frac{3}{8}$	$1\frac{11}{16}$	$\frac{1}{4}$	$\frac{9}{16}$
$1\frac{1}{4}$	$7\frac{1}{2}$	$3\frac{3}{4}$	$1\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$2\frac{1}{8}$	$\frac{7}{16}$	$1\frac{7}{8}$	$\frac{5}{16}$	$\frac{5}{8}$
$1\frac{3}{8}$	$8\frac{1}{4}$	$4\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$\frac{11}{16}$	$2\frac{5}{16}$	$\frac{7}{16}$	$2\frac{1}{16}$	$\frac{3}{8}$	$\frac{11}{16}$
$1\frac{1}{2}$	9	$4\frac{1}{2}$	$1\frac{5}{8}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$
$1\frac{5}{8}$	$9\frac{3}{4}$	$4\frac{7}{8}$	$1\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{5}{8}$	$\frac{13}{16}$	$2\frac{11}{16}$	$\frac{9}{16}$	$2\frac{7}{16}$	$\frac{7}{16}$	$\frac{13}{16}$
$1\frac{3}{4}$	$10\frac{1}{2}$	$5\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{7}{8}$	$1\frac{3}{4}$	$\frac{7}{8}$	$2\frac{7}{8}$	$\frac{9}{16}$	$2\frac{5}{8}$	$\frac{7}{16}$	$\frac{7}{8}$
$1\frac{7}{8}$	$11\frac{1}{4}$	$5\frac{5}{8}$	2	$3\frac{1}{16}$	$1\frac{7}{8}$	$\frac{15}{16}$	$3\frac{1}{16}$	$\frac{5}{8}$	$2\frac{13}{16}$	$\frac{1}{2}$	$\frac{15}{16}$
2	12	6	$2\frac{1}{4}$	$3\frac{3}{8}$	2	1	$3\frac{3}{8}$	$1\frac{1}{16}$	3	$\frac{1}{2}$	1
$2\frac{1}{8}$	$12\frac{3}{4}$	$6\frac{3}{8}$	$2\frac{3}{8}$	$3\frac{9}{16}$	$2\frac{1}{8}$	$1\frac{1}{16}$	$3\frac{9}{16}$	$1\frac{1}{16}$	$3\frac{3}{16}$	$\frac{9}{16}$	$1\frac{1}{16}$
$2\frac{1}{4}$	$13\frac{1}{2}$	$6\frac{3}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$3\frac{3}{4}$	$\frac{3}{4}$	$3\frac{3}{8}$	$\frac{9}{13}$	$1\frac{1}{8}$
$2\frac{3}{8}$	$14\frac{1}{4}$	$7\frac{1}{8}$	$2\frac{5}{8}$	$3\frac{15}{16}$	$2\frac{3}{8}$	$1\frac{3}{16}$	$3\frac{15}{16}$	$1\frac{3}{16}$	$3\frac{9}{16}$	$\frac{5}{8}$	$1\frac{3}{16}$
$2\frac{1}{2}$	15	$7\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{8}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$4\frac{1}{8}$	$1\frac{3}{16}$	$3\frac{3}{4}$	$\frac{5}{8}$	$1\frac{1}{4}$
$2\frac{5}{8}$	$15\frac{3}{4}$	$7\frac{7}{8}$	$2\frac{7}{8}$	$4\frac{5}{16}$	$2\frac{5}{8}$	$1\frac{5}{16}$	$4\frac{5}{16}$	$\frac{7}{8}$	$3\frac{15}{16}$	$\frac{11}{16}$	$1\frac{5}{16}$

U. S. STANDARD HEXAGON BOLTS AND NUTS.

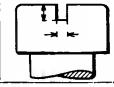



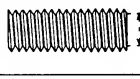
Diam-eter of Tap.	Threads per Inch.	Mill.	Across Corners.	Thickness. Thin.	Thickness. U. S. Standard	Thickness. Thick.	Depth of Thread.	Exact Size of Hole.	Tap Drill Used.	Width of Flat.	Area at Root of Thread.	Safe Strain in lbs. Iron at 50.000 lbs. per sq. in. Factor of Safety —5—
1-4	*22	1-2	37-64	3-16	1-4	3-8	.0295	.1910	.1960	.0056	.0286	286
5-16	18	19-32	11-16	1-4	5-16	7-16	.0361	.2403	.2460	.0069	.0452	452
3-8	16	11-16	51-64	1-4	3-8	1-2	.0406	.2938	19-64	.0078	.0677	677
7-16	14	25-32	29-32	5-16	7-16	5-8	.0464	.3447	2 -64	.0089	.0932	932
1-2	13	7-8	1 1-64	3 8	1-2	3-4	.0500	.4001	13-32	.0 96	.1257	1257
9-16	12	31-32	1 1-8	7-16	9-16	7 8	.0542	.4542	15-32	.0104	.1620	1620
5-8	11	1 1-16	1 15 64	7-16	5-8	1	.0590	.5069	33-64	.0114	.2018	2018
3-4	10	1 1-4	1 29-64	1-2	3-4	1 1-8	.0650	.6201	5-8	.0125	.3020	3020
7-8	9	1 7-16	1 43-64	9-16	7-8	1 3-8	.0722	.7307	47-64	.0139	.4194	4194
1	8	1 5-8	1 7-8	5-8	1	1 1-2	.0812	.8376	27-32	.0156	.5509	5509
1 1-8	7	1 13-16	2 3-32	11-16	1 1-8	1 3-4	.0928	.9394	61-64	.0179	.6930	6930
1 1-4	7	2	2 5-16	3-4	1 1-4	1 7-8	.0928	1 0644	1 5 64	.0179	.8890	8890
1 3-8	6	2 3-16	2 17-32	13-16	1 3-8	2	.1083	1.1585	1 11-64	.0208	1.0540	10540
1 1-2	6	2 3-8	2 3-4	7-8	1 1-2	2 1-4	.1083	1.2835	1 19-64	.0208	1.2930	12935
1 3-4	5	2 3-4	3 3-16	1	1 3-4	2 5-8	.1300	1.4902	1 33-64	.0250	1.7440	17441
2	4 1-2	3 1-8	3 39 64	1 1-8	2	3	.1444	1 7113	1 23-32	.0278	2.3000	33000
2 1-4	4 1-2	3 1-2	4 3-64	1 1-4	2 1-4	3 3-8	.1444	1 9613	1 31-32	.0278	3.0210	30214
2 1-2	4	3 7-8	4 31-64	1 3-8	2 1-2	3 3-4	.1625	2 1752	2 3-16	.9313	3.7140	37149
2 3-4	4	4 1-4	4 29-32	1 1-2	2 3-4	4	.1625	2 4252	2 7-16	.0313	4.6180	46181
3	3 1-2	4 5-8	5 11-32	1 5-8	3	4 1-2	.1857	2.6288	2 41-64	.0357	5 4279	54275

*U. S. Standard Threads 20.

1. Mill or distance across flats equals 1½ times the diameter of Tap. plus ⅛ inch.
2. Across corners or long diameter equals 1.155 times the mill. Table gives nearest 1-64 larger.
3. Exact depth of thread equals .65 times the pitch. Width of flat on thread equals ⅛ the pitch.
4. Exact size of hole U. S. Standard equals diameter Tap minus $\frac{1.299}{\text{No. threads per in.}}$ Tap Drill nearest 1-64 larger.
5. Bolt Heads same dimensions as Nuts.

ROUND HEAD MACHINE SCREWS.

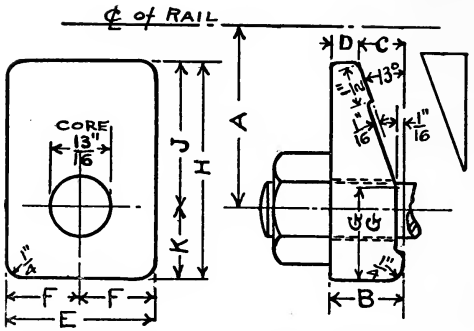




Diam. of Body.	Thds. per Inch.	Diam. of Head	Depth of C'nter Bore.	Round on Head.	Size of Slot. Width.	Size of Slot. Depth.	Depth of Thread	Exact Size at Bottom	Tap Drill Used.	Clear-ance.	Width of Flat.	Area at Root of Thread.	Safe Strain In Lbs. Iron at 50,000 lbs. per sq. in. Factor of Safety 5
1/16	64	1/8	1/16	6/64	.020	.020	.0101	.0423	3/64 .0468	.0045	.0019	0014	14
3/32	48	3/32	1/16	6/64	.020	.020	0135	.0667	No. 49, .0730	.0063	.0026	.0034	34
1/8	40	11/64	3/32	3/32	.025	1/32	.0162	.0926	No. 40, .0980	.0054	.0031	.0067	67
5/32	32	7/32	3/32	3/32	.025	1/32	.0203	.1156	No. 31, .1200	.0044	.0039	.0104	104
1/16	32	1/4	3/32	3/32	.030	6/64	.0203	.1469	No. 24, .1520	.0051	.0039	.0169	169
3/32	24	1/16	1/8	3/32	.040	8/64	.0270	.1646	No. 18, .1695	.0048	.0052	.0212	212
1/4	*22	11/32	1/8	3/32	.050	1/16	.0295	.1910	No. 9, .1960	.0050	.0056	.0286	286
5/16	18	1/16	1/16	6/64	.060	6/64	.0361	.2403	D, .2460	.0057	.0069	.0452	452
3/8	16	1/2	1/4	6/64	.070	3/32	.0406	.2938	19/64	.0030	.0078	.0677	677
7/16	14	9/16	1/4	6/64	.080	7/64	.0464	.3447	23/64	.0146	.0089	.0932	932
1/2	13	19/32	5/16	6/64	.090	1/8	.0500	.4001	13/32	.0051	.0096	.1257	1257
9/16	12	3/4	3/8	6/64	.100	9/64	.0542	.4542	15/32	.0145	.0104	.1620	1620
5/8	11	7/8	7/16	1/16	.120	5/32	.0590	.5069	33/64	.0087	.0114	.2018	2018
3/4	10	1 1/16	1/2	1/16	.140	3/16	.0650	.6201	5/8	.0049	.0125	.3020	3020
7/8	9	1 3/16	9/16	1/16	.160	7/32	.0722	.7307	47/64	.0036	.0139	.4194	4194
1	8	1 3/8	5/8	1/16	.180	1/4	.0812	.8376	27/32	.0061	.0156	.5509	5509

*U. S. Standard Threads 20.

1. Exact depth of thread equals .65 times the pitch. Width of flat on thread equals ⅛ of the pitch.
2. Exact size of bottom of thread U. S. Standard equals diameter of Tap minus $\frac{1.299}{\text{No. thds. per in.}}$ Tap drill nearest 6/64 larger. Width of slots equals 3/16 of diameter of body (approximately).
3. Depth of slots equals ¼ of diameter of body (approximately).



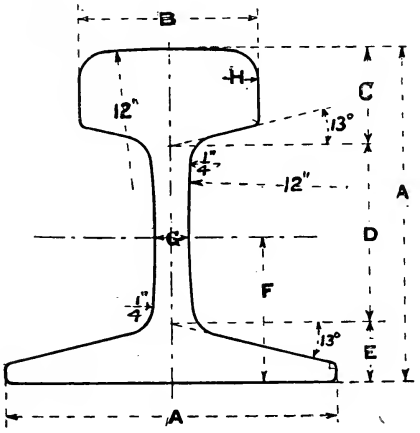
STANDARD RAIL CLIPS.

	Distance A for												
	30	35	40	45	50	B	C	D	E	F	G	H	J
30 to 50 pound rails.	1½	1 11/16	1⅞	2 1/16	2¼	¾	7/16	5/16	1¼	⅞	½	2	1⅛
	1¾	1 15/16	2⅛	2 5/16	2½	¾	7/16	5/16	1¾	⅞	¾	2¼	1⅜
	2	2 3/16	2⅜	2 9/16	2¾	¾	7/16	5/16	1¾	⅞	1	2½	1⅝
	2¼	2 7/16	2⅝	2 13/16	3	¾	7/16	5/16	1¾	⅞	1¼	2¾	1⅞
	2½	2 11/16	2⅞	3 1/16	3¼	¾	7/16	5/16	1¾	⅞	1½	3	2⅛

	Distance A for												
	55	60	65	70	75	B	C	D	E	F	G	H	J
55 to 75 pound rails.	1¾	1⅞	2	2⅛	2¼	1 5/16	1 9/32	1 1/32	2	1	⅜	2¼	1¼
	2	2⅛	2¼	2⅜	2½	1 5/16	1 9/32	1 1/32	2	1	⅝	2½	1½
	2¼	2⅜	2½	2⅝	2¾	1 5/16	1 9/32	1 1/32	2	1	⅞	2¾	1¾
	2½	2⅝	2¾	2⅞	3	1 5/16	1 9/32	1 1/32	2	1	1⅛	3	2
	2¾	2⅞	3	3⅛	3¼	1 5/16	1 9/32	1 1/32	2	1	1⅜	3¼	2¼

	Distance A for												
	80	85	90	95	100	B	C	D	E	F	G	H	J
80 to 100 pound rails.	2	2⅛	2¼	2⅜	2½	1⅛	¾	⅜	2¼	1⅛	¼	2½	1⅜
	2¼	2⅜	2½	2⅝	2¾	1⅛	¾	⅜	2¼	1⅛	½	2¾	1⅝
	2½	2⅝	2¾	2⅞	3	1⅛	¾	⅜	2¼	1⅛	¾	3	1⅞
	2¾	2⅞	3	3⅛	3¼	1⅛	¾	⅜	2¼	1⅛	1	3¼	2⅛
	3	3⅛	3¼	3⅜	3½	1⅛	¾	⅜	2¼	1⅛	1¼	3½	2⅜

The dimension K is the same as F.



Standard Rail Sections

Wt.	16	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
A	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 11/16	3 7/8	4 1/16	4 1/4	4 7/16	4 5/8	4 13/16	5	5 3/16	5 3/8	5 9/16	5 3/4
B	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 7/16	2 5/8	2 1/2	2 9/16	2 5/8	2 11/16	2 3/4
C	5/8	45/64	25/32	55/64	15/16	1 1/64	1 1/16	1 1/8	1 13/64	1 7/32	1 9/32	1 11/32	1 27/64	1 1/2	1 35/64	1 19/32	1 43/64	1 5/64
E	27/64	31/64	37/64	17/32	37/64	39/64	21/32	11/16	23/32	49/64	25/32	13/16	27/32	7/8	57/64	59/64	15/16	31/32
F	1 15/64	1 9/32	1 21/64	1 13/64	1 37/128	1 41/128	1 47/64	1 23/32	1 51/128	1 15/32	1 31/32	2 3/64	2 1 5/128	2 3/16	2 7/64	2 45/128	2 55/128	2 65/128
G	1 5/16	1 1/16	1 9/64	1 1/2	1 23/64	1 25/64	1 27/64	1 7/16	1 15/32	1 31/64	1 1/2	1 33/64	1 17/32	1 35/64	1 9/16	1 9/16	1 9/16	1 9/16
*X	1 3/8	1 3/8	1 1/2	1 1/2	1 3/4	2	2	2 1/4	2	2 1/4	2 1/2	2 1/2	2 1/2	2 3/4	2 3/4	3	4	4

*"X" is the gage of holes in flange.

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PLATE 4

PLATE 4

This plate is of a small I-beam bridge drawn at a scale of 1" = 1 ft.

The size of the beams is given so that the proportion can be secured from the table, page 7.

Pieces of I-beams are used for seperators and the spacing for the riveting is given at the left and all rivets are $\frac{3}{4}$".

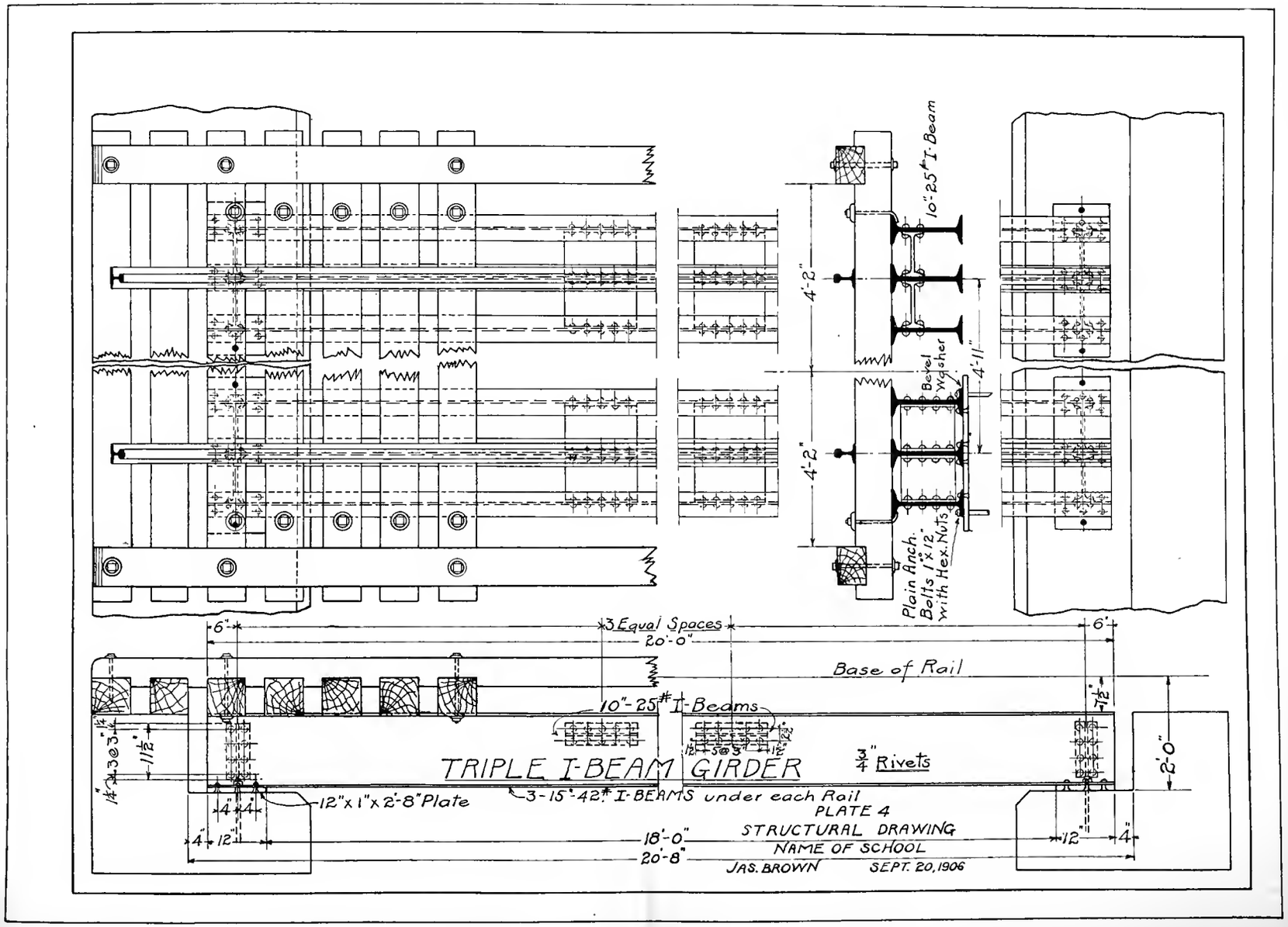


PLATE 5

PLATE 5

This represents a girder 6'-4" deep built up of $\frac{5}{16}$" plate 6'-3$\frac{1}{2}$" wide and stiffened at regular intervals.

A top and two sectional views are shown beside the side elevation.

The Scale is 1"=1 ft.

Rivets $\frac{7}{8}$ and $\frac{3}{4}$ are used.

The strips under the vertical angles are called fillers or "fills" and must be as thick as the flange angles, in this case $\frac{13}{16}$".

A portion of the top and bottom is covered with three plates.

The girder is 60'-4" long but only the angles and cover plates run through, the web plate being spliced as shown.

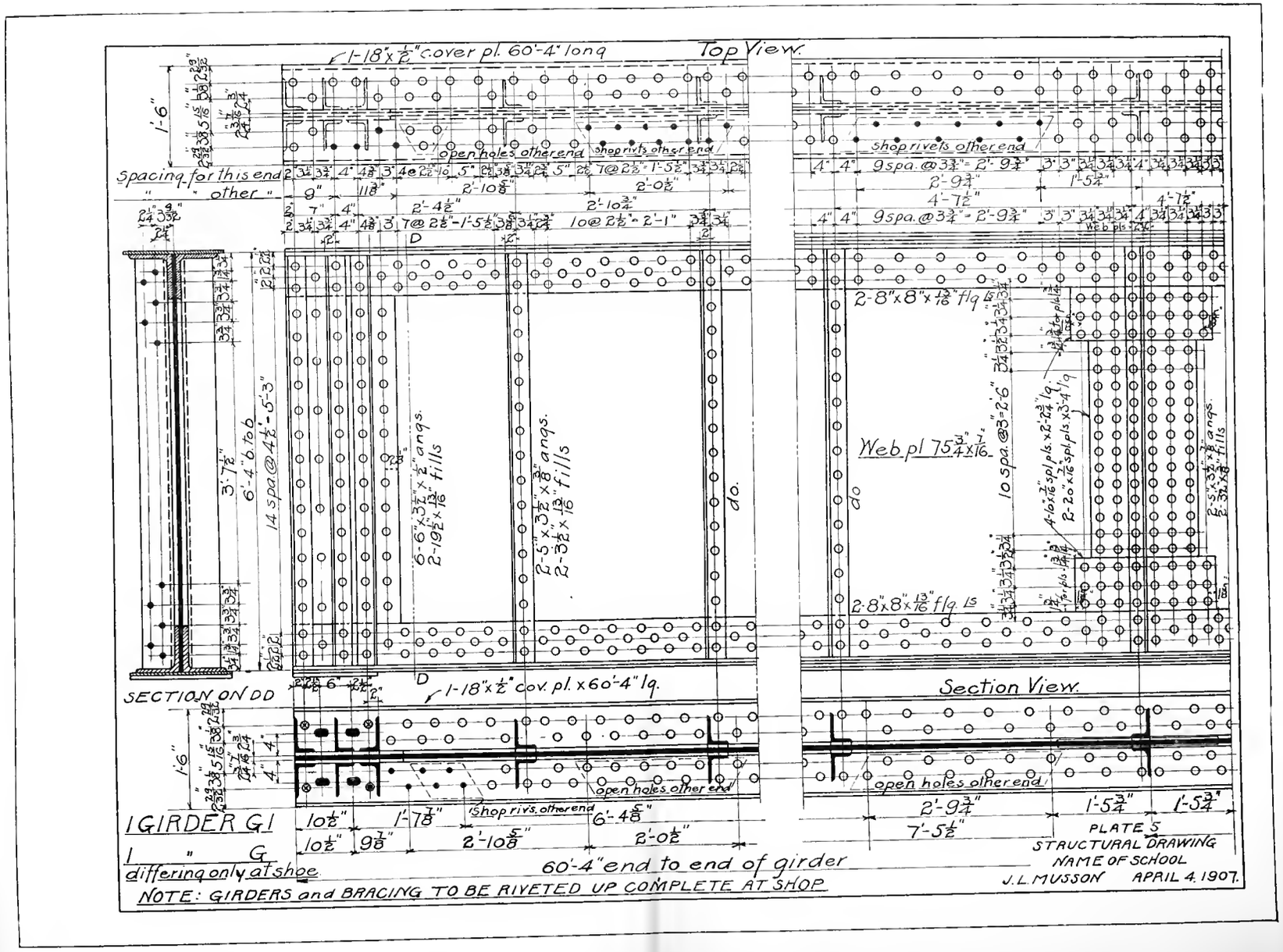


PLATE 6

PLATE 6

This plate shows some bracing made of angles and plates to go between girders such as shown on plate 5.

Where the size of rivets are not shown see table on pages 14-15-16.

The triangles marked 1'-0", $11\frac{1}{8}$" and 1'-0", $1\frac{11}{32}$" indicate the slope of the angle braces, that is those at the left slope $11\frac{1}{8}$" in every 12" or one foot. Locate the first rivet hole, at the lower left corner, then lay out 12" to the right on the horizontal line, then erect a perpendicular $11\frac{1}{8}$", and through that point and the first rivet hole draw the center line of the angle sloping upward toward the right.

Saale of this plate is 1"=1 ft.

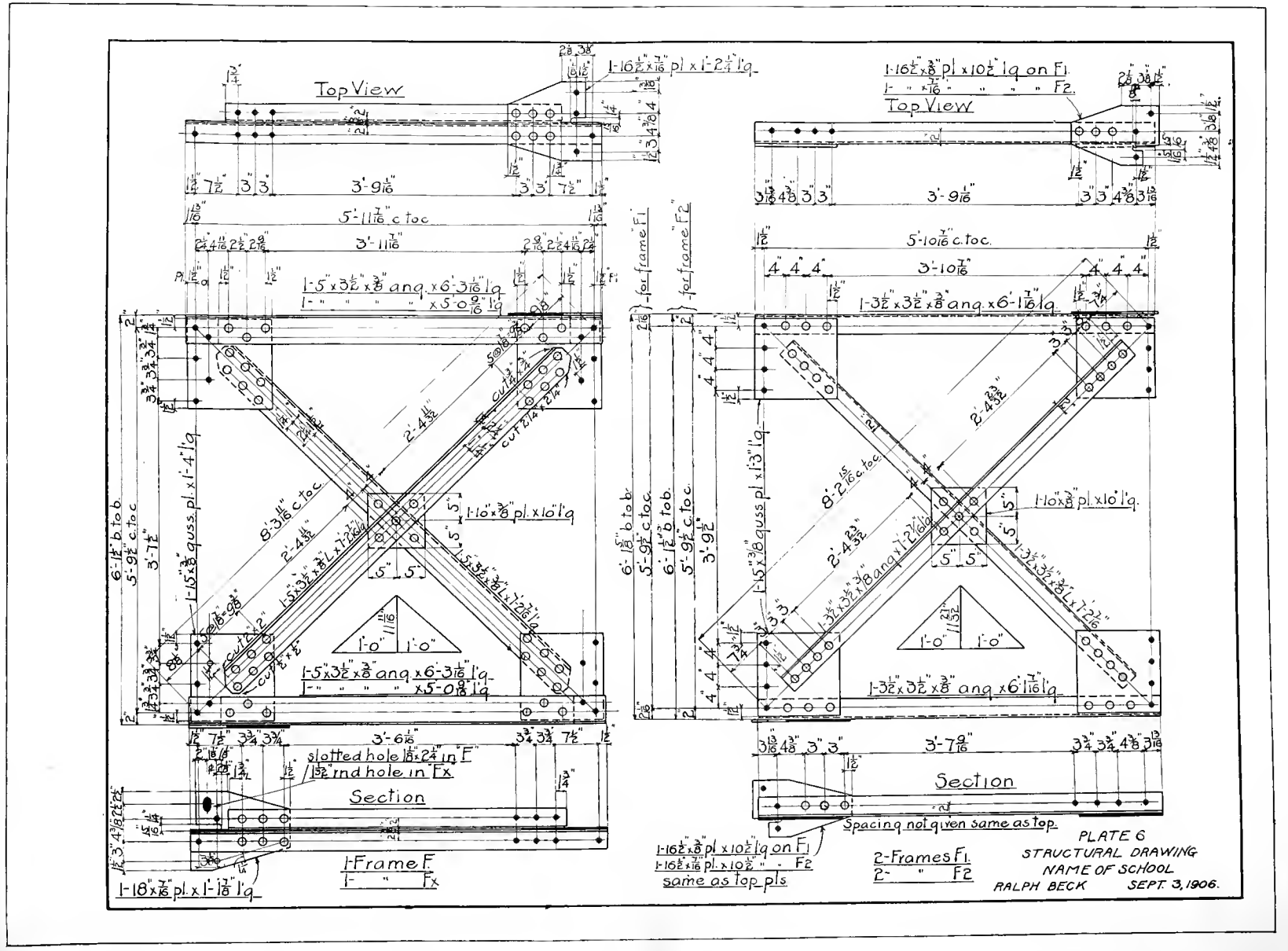


PLATE 7

PLATE 7

Additional bracing, the base case casting, anchor bolts and general layouts of the girders of Plate 5 are here shown.

The notches in the plates are to fit the stiffening angles of the girders. Check the holes with those on girder, Plate 5, and use same size rivets and where not specified use table, page 14-15-16.

The scale for this plate is 1"=1 ft. for the bracing, and 2"=1 ft. for the casting and ¼"=1 ft. for diagram of bracing and the small view at the right of the end of the girder.

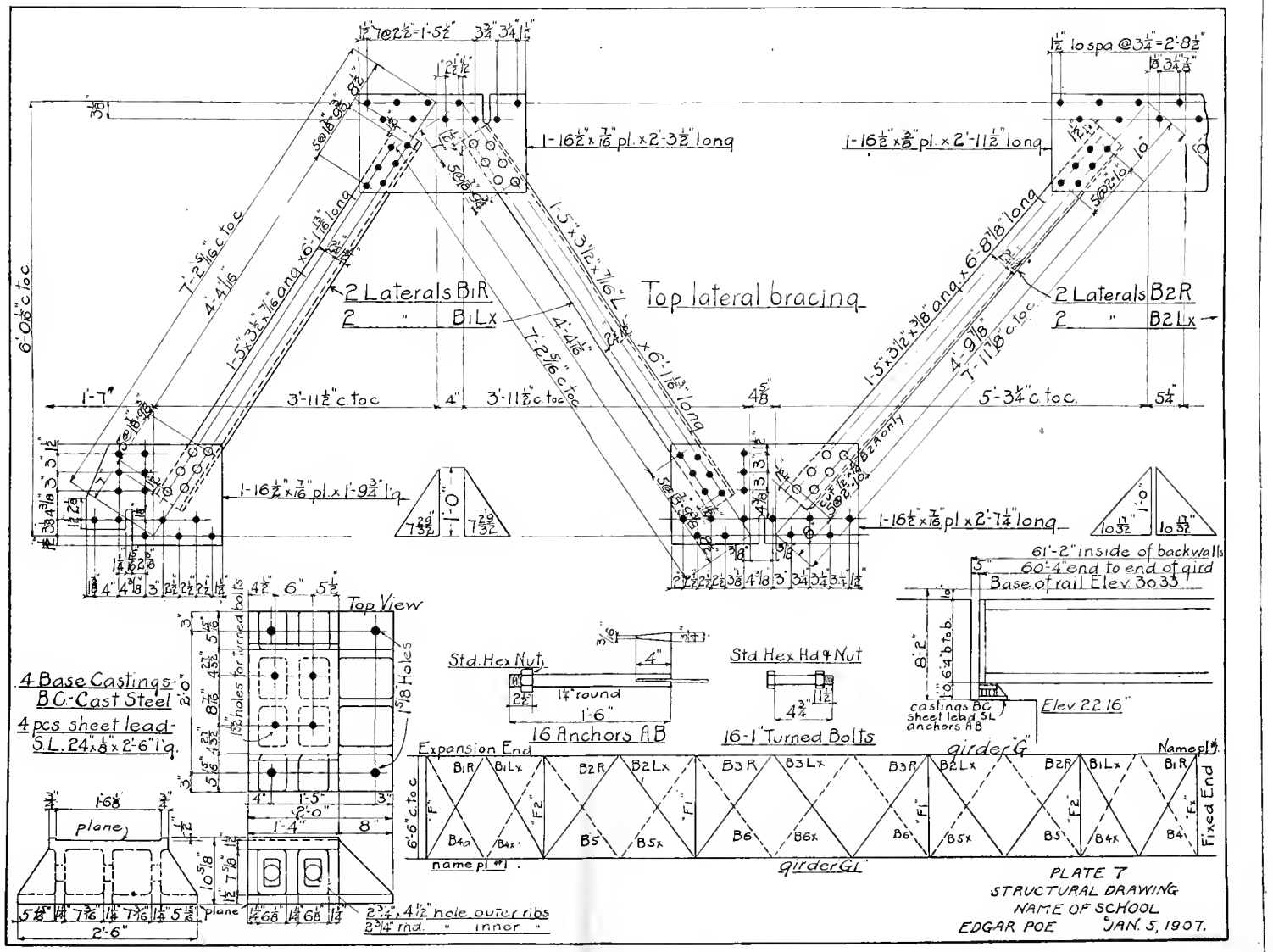


PLATE 8

PLATE 8

This shows three views of a chord for a bridge drawn at a scale of 1" =1 ft.
The top line of the top view is 3½" from the top border line.
The bottom view is 2½" from the lower border line.
Place the the middle view 1½" above the bottom one.

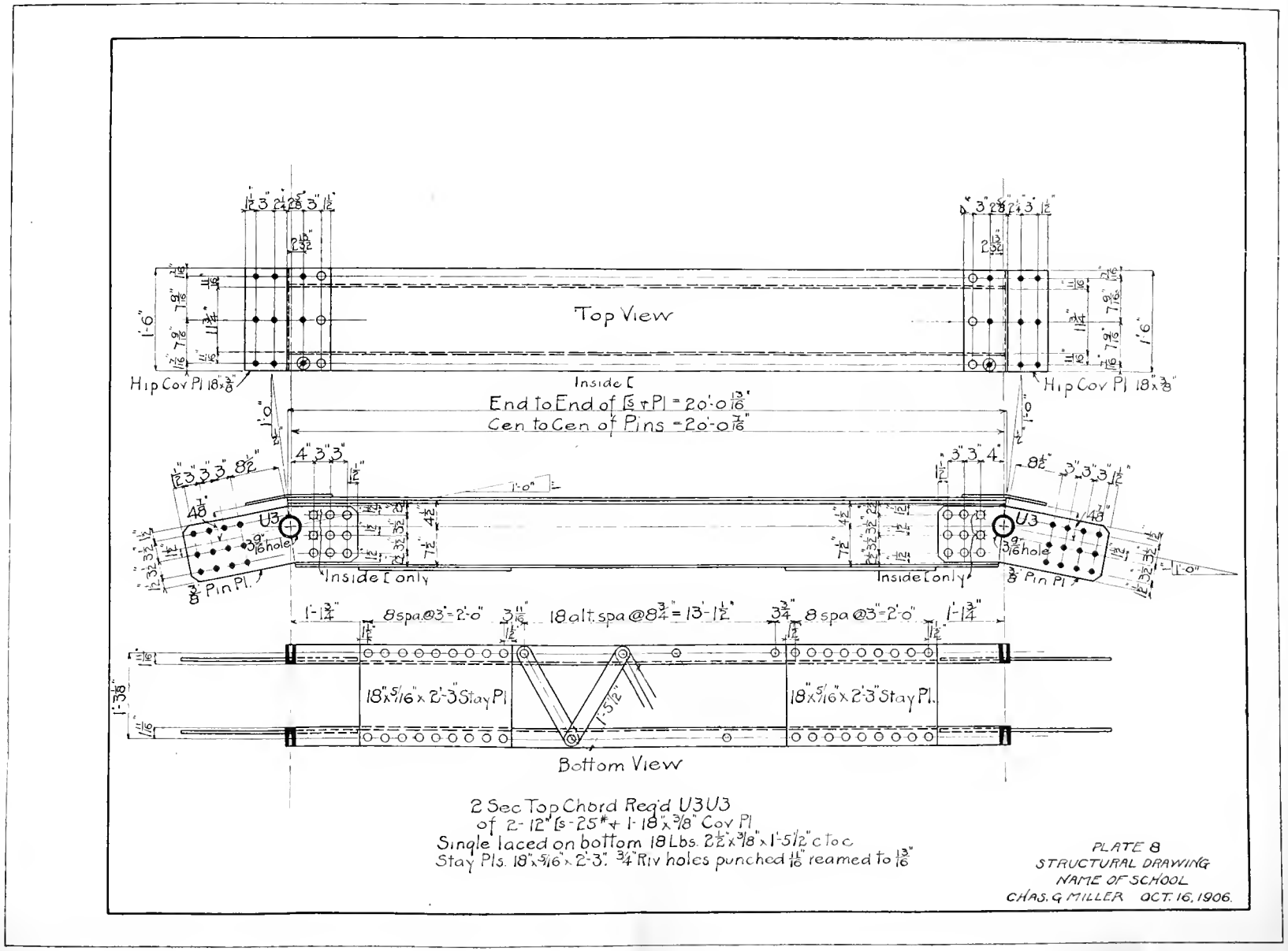
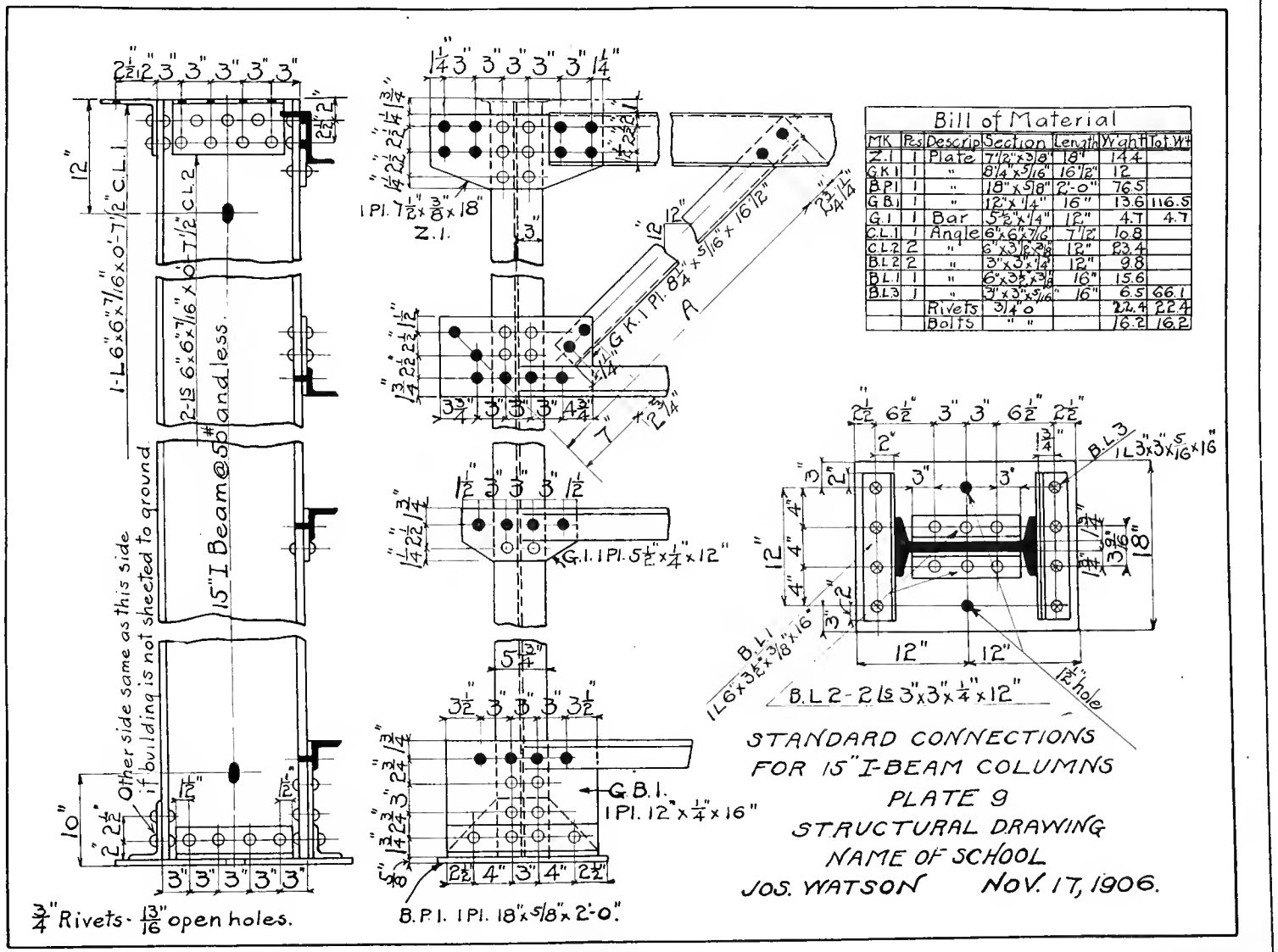

Top View
Hip Cov Pl 18"x⅜"
Inside ⊏
End to End of ⊏s & Pl = 20'-0 13/16"
Cen to Cen of Pins = 20'-0 7/16"
Inside ⊏ only
⅞" Pin Pl.
3 9/16" hole
U3
Bottom View
8 spa @3"=2'-0"
18 alt. spa @8¾"=13'-1½"
18"x5/16"x 2'-3" Stay Pl
1'-5½"
2 Sec Top Chord Req'd U3U3
of 2-12"⊏s-25#+ 1-18"x⅜" Cov Pl
Single laced on bottom 18 Lbs. 2½"x⅜"x1'-5½" c to c
Stay Pls. 18"x5/16"x 2'-3". ¾" Riv holes punched 11/16" reamed to 13/16"
PLATE 8
STRUCTURAL DRAWING
NAME OF SCHOOL
CHAS. G MILLER OCT. 16, 1906.

PLATE 9

PLATE 9

This is a 15" I-Beam column with detail of the base and a table of the parts needed on the job. The sheet is drawn to the scale of 1½" = 1 ft.

From the table of proportions of I-beams the section can be drawn.


1-L 6"x6"x7/16"x0'-7½" C.L.1
2-ls 6"x6"x7/16"x0'-7½" C.L.2
15" I Beam @ 58# and less.
Other side same as this side if building is not sheeted to ground
¾" Rivets - 13/16" open holes.
G.K.1 1 Pl. 8¼" x 5/16" x 16'12"
G.1 1 Pl. 5½" x ¼" x 12"
G.B.1. 1 Pl. 12" x ¼" x 16"
B.P.1. 1 Pl. 18" x 5/8" x 2'-0"
B.L.3 1 L 3"x3"x5/16"x16"
B.L.1 1 L 6"x3½"x3/8"x18"
B.L.2 - 2 ls 3"x3"x¼"x12"
12½" hole
STANDARD CONNECTIONS FOR 15" I-BEAM COLUMNS
PLATE 9
STRUCTURAL DRAWING
NAME OF SCHOOL
JOS. WATSON NOV. 17, 1906.

Bill of Material

MK	Pcs	Descrip	Section	Length	Weight	Tot Wt
Z.1	1	Plate	7'12"x3/8"	18"	14.4	
GK1	1	"	8¼ x 5/16"	16'12"	12	
BP1	1	"	18"x 5/8"	2'-0"	76.5	
GB1	1	"	12"x ¼"	16"	13.6	116.5
G.1	1	Bar	5½"x¼"	12"	4.7	4.7
C.L.1	1	Angle	6"x6"x7/16"	7'12"	108	
C.L.2	2	"	6"x3½"x3/8"	12"	83.4	
B.L.2	2	"	3"x3"x¼"	12"	9.8	
B.L.1	1	"	6"x3½"x3/8"	16"	15.6	
B.L.3	1	"	3"x3"x5/16"	16"	6.5	66.1
		Rivets	3/4" ø		22.4	22.4
		Bolts	" "		16.2	16.2

PLATE 10

PLATE 10

This sheet shows three views of a built-up column made of a plate and angles.

The top view is broken and the plan of the base or foot of the column inserted. This is often done where the view is uniform for some length.

The scale of the drawing is $\frac{3}{4}$" to 1 ft.

The top line of the plate in the top view is $3\frac{1}{4}$ inches from the top border line. The left end $\frac{5}{8}$ inches from the border while the right end is $1\frac{1}{2}$" from the border line. The lower edge of the bottom view should be 2" from the border line.

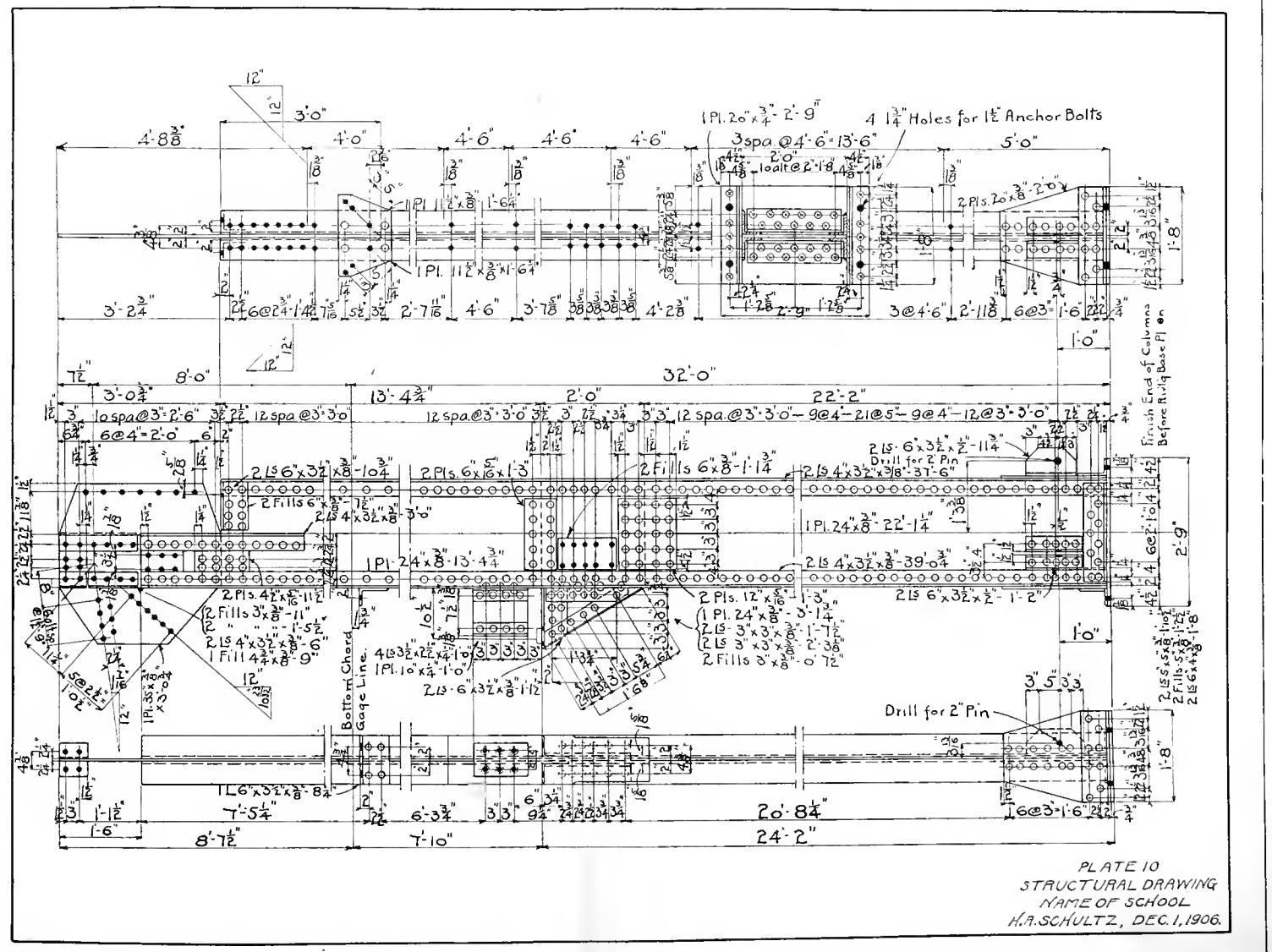


PLATE 11

PLATE 11

This is details of a roof truss built partly of wood and structural shapes including the rods and turn buckets.

The side view is broken to aid getting it on the sheet at a larger scale. The scale of the truss is $\frac{3}{4}$"=1 ft. but the castings are drawn $1\frac{1}{2}$=1 ft.

The center line of the pin hole in the castings is $1\frac{1}{2}$ inches from the top border and the left view $\frac{3}{4}$ inches from the left line.

The views are $\frac{1}{2}$" apart.

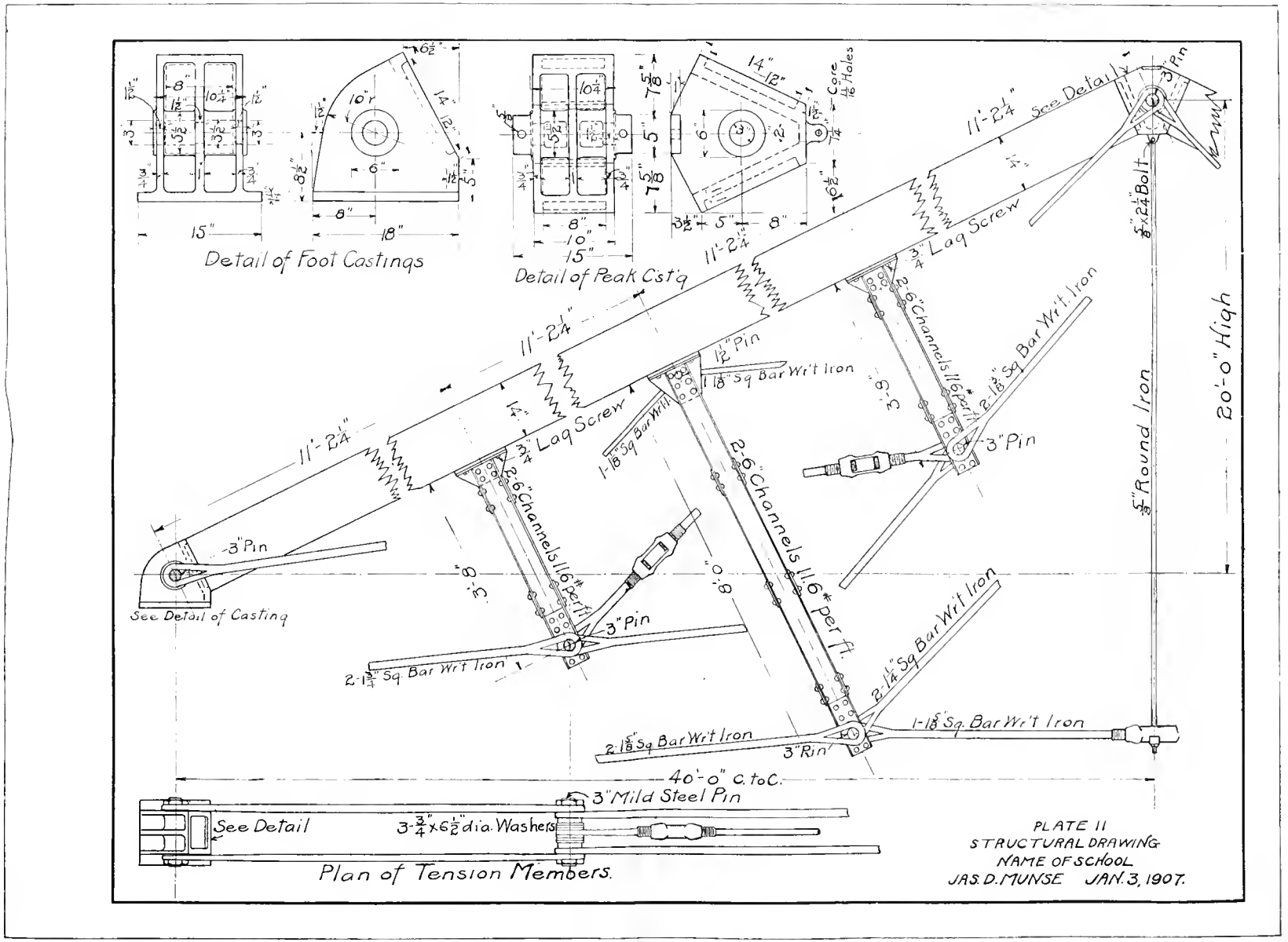


PLATE 12

PLATE 12

This represents part of a roof truss for a foundry building. The scale is $\frac{3}{4}$"=1 ft. the center line is $2\frac{3}{8}$ inches from the right border and the bottom line of the lower angle is $3\frac{1}{2}$ inches from the bottom border.

Everything will have to be drawn on the basis of the center lines and then lay out the edges and flange thickness of the angles from them.

The lay out in the upper right hand corner is drawn to a scale of $\frac{1}{16}$"=1 ft. and is laid out $\frac{1}{2}$" from the border.

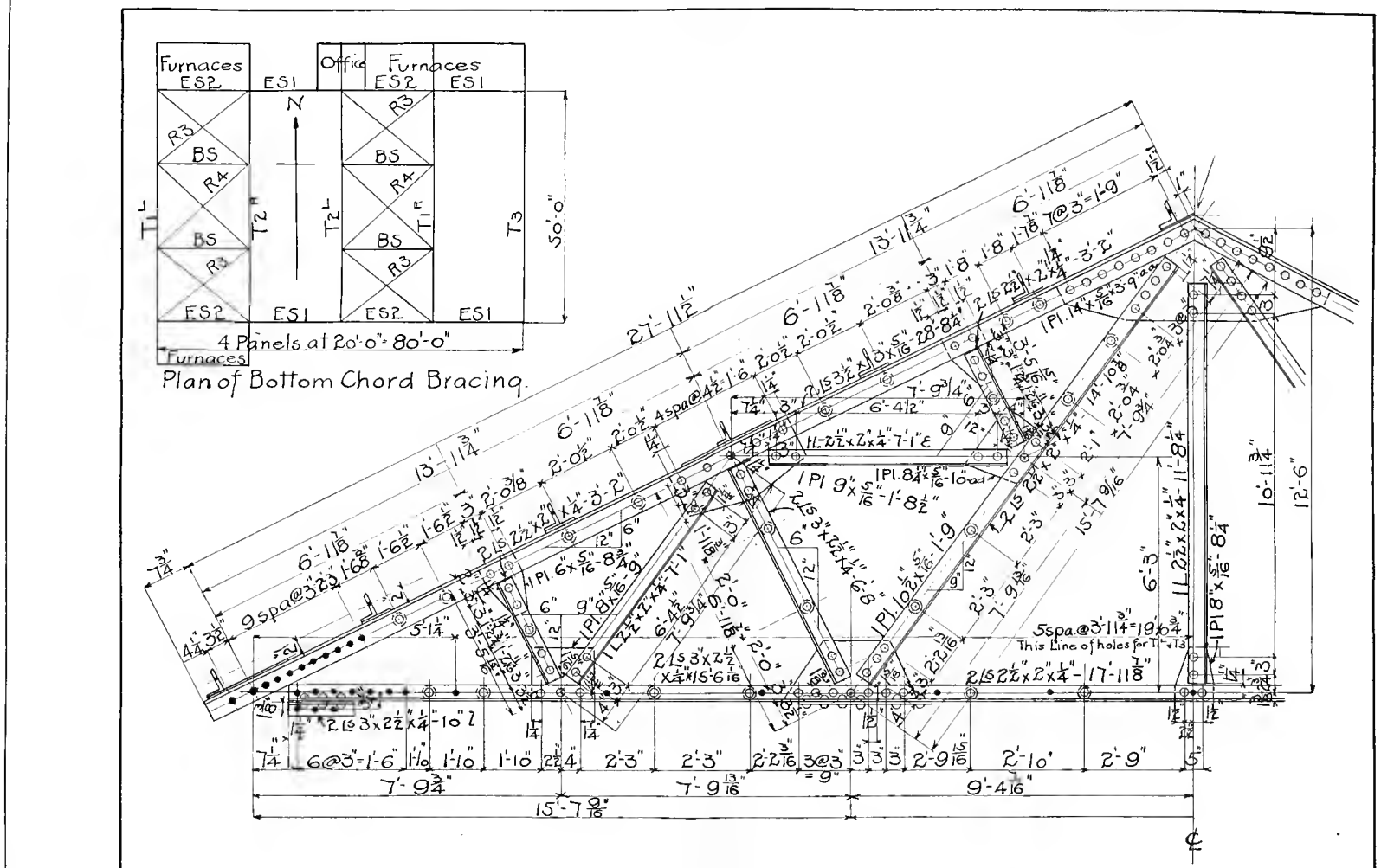


PLATE 13

PLATE 13

This represents the top chord and an end post of a bridge, the top view of the post being broken into the border line.

The scale is $\frac{3}{4}$"=1 ft. while the diagram is $\frac{3}{16}$"=1 ft.

The lower line of the diagram is 1" from the bottom border and its top and bottom chord are 18 feet apart center to center.

L_1 and L_0 are 16'-6$\frac{7}{8}$" apart and so is L_1 and L_2, L_2 and L_3.

From L_2 to U_1 (pin) is 18 ft., this will give the slope of the end post.

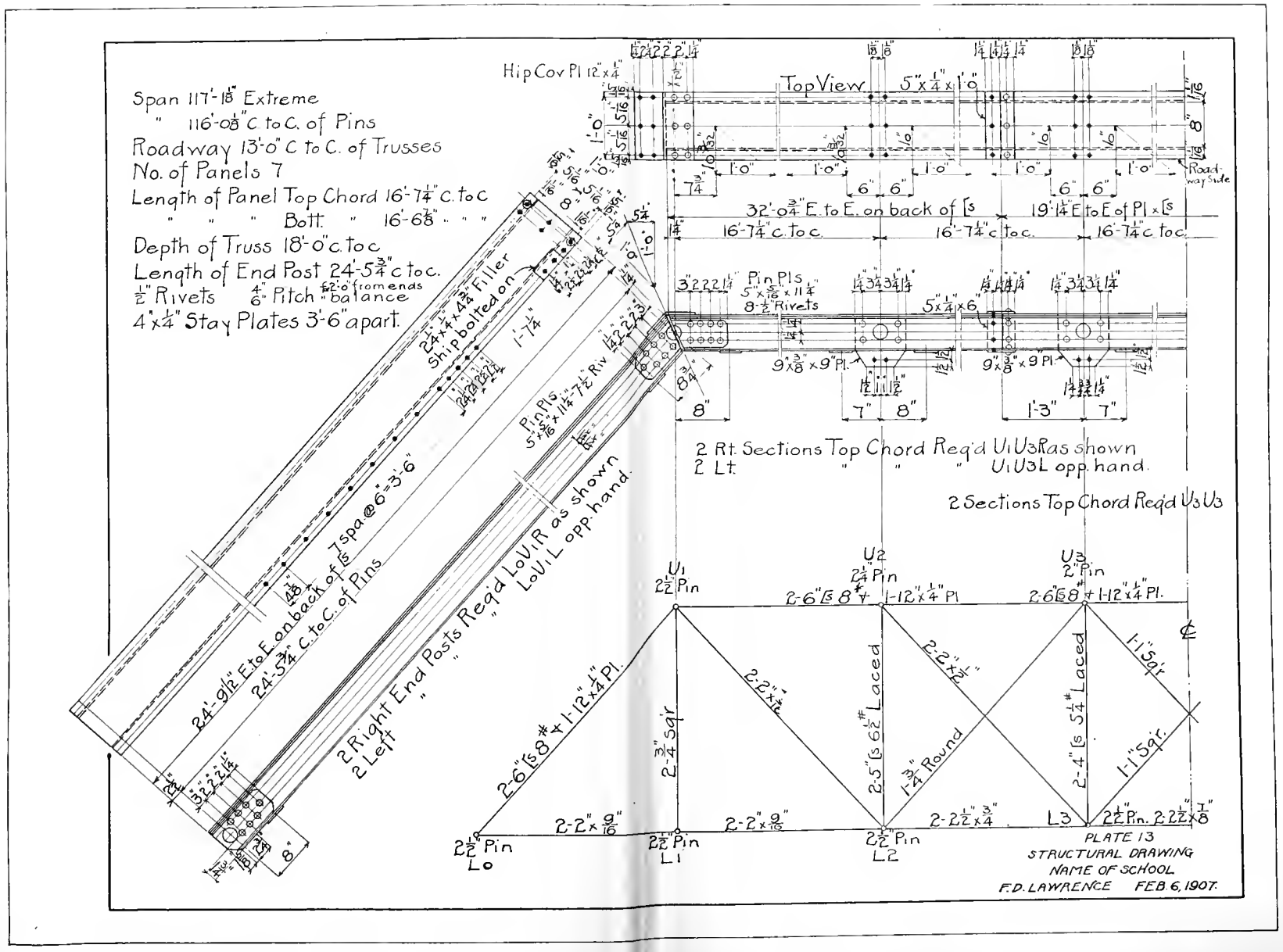

Span 117'-18" Extreme
" 116'-0⅜" C. to C. of Pins
Roadway 13'-0" C to C. of Trusses
No. of Panels 7
Length of Panel Top Chord 16'-7¼" c. to c
" " " Bott. " 16'-6⅞" " " "
Depth of Truss 18'-0" c. to c
Length of End Post 24'-5¾" c to c.
½" Rivets 4" 6" Pitch "balance
4"x¼" Stay Plates 3'-6" apart.
Hip Cov Pl 12"x¼"
Top View 5"x¼"x1'-0"
Road way Side
32'-0¾" E. to E. on back of [s
19'-1¼" E to E of Pl x [s
16'-7¼" c. to c.
Pin Pls 5"x⅝"x11¼" 8-½" Rivets
5"x¼"x6"
9"x⅜"x9" Pl.
2 Rt. Sections Top Chord Req'd U1U3R as shown
2 Lt. " " " U1U3L opp. hand.
2 Sections Top Chord Req'd U3U3
2 Right End Posts Req'd LoU1R as shown
2 Left " " LoU1L opp. hand
24'-9½" E to E on back of [s
24'-5¾" C. to C. of Pins
7 spa @ 6"=3'-6"
2½"x4"x4¾" Filler
Ship bolted on
Pin Pls 5"x⅝"x11¼" 7½" Riv
U1 2½" Pin
U2 2¼" Pin
U3 2" Pin
2-6"[s 8#+1-12"x¼" Pl.
2-2"x¼"
2-3" sq'r
2-5"[s 6½# Laced
1-¾" Round
2-4"[s 5¼# Laced
1-1"sq'r.
2-2"x9/16"
2-2½"x¾"
L0
L1
L2
L3
2½" Pin. 2-2½"x⅞"
PLATE 13
STRUCTURAL DRAWING
NAME OF SCHOOL
F.D. LAWRENCE FEB. 6, 1907.

PLATE 14

PLATE 14

This is the details of a lot of concrete foundations, also the layout for the set for a foundry building. The scale of the detail is $\frac{3}{4}$"=1 ft. for the iron part and $\frac{1}{8}$"=1 ft. for the foundations.

The general layout is drawn to several scales so to get the whole thing on the sheet.

A little care will enable the student to arrange all, properly.

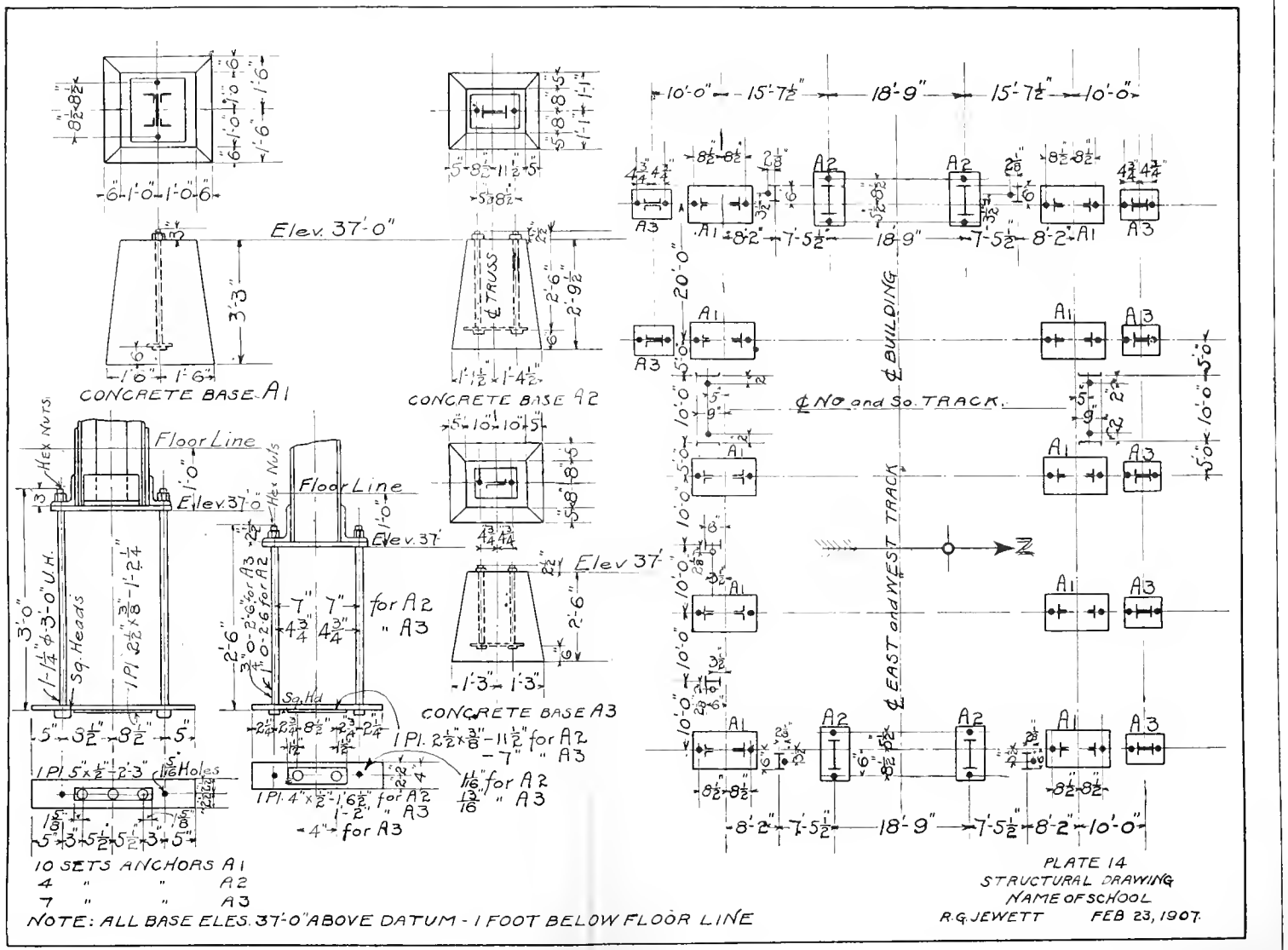


PLATE 15

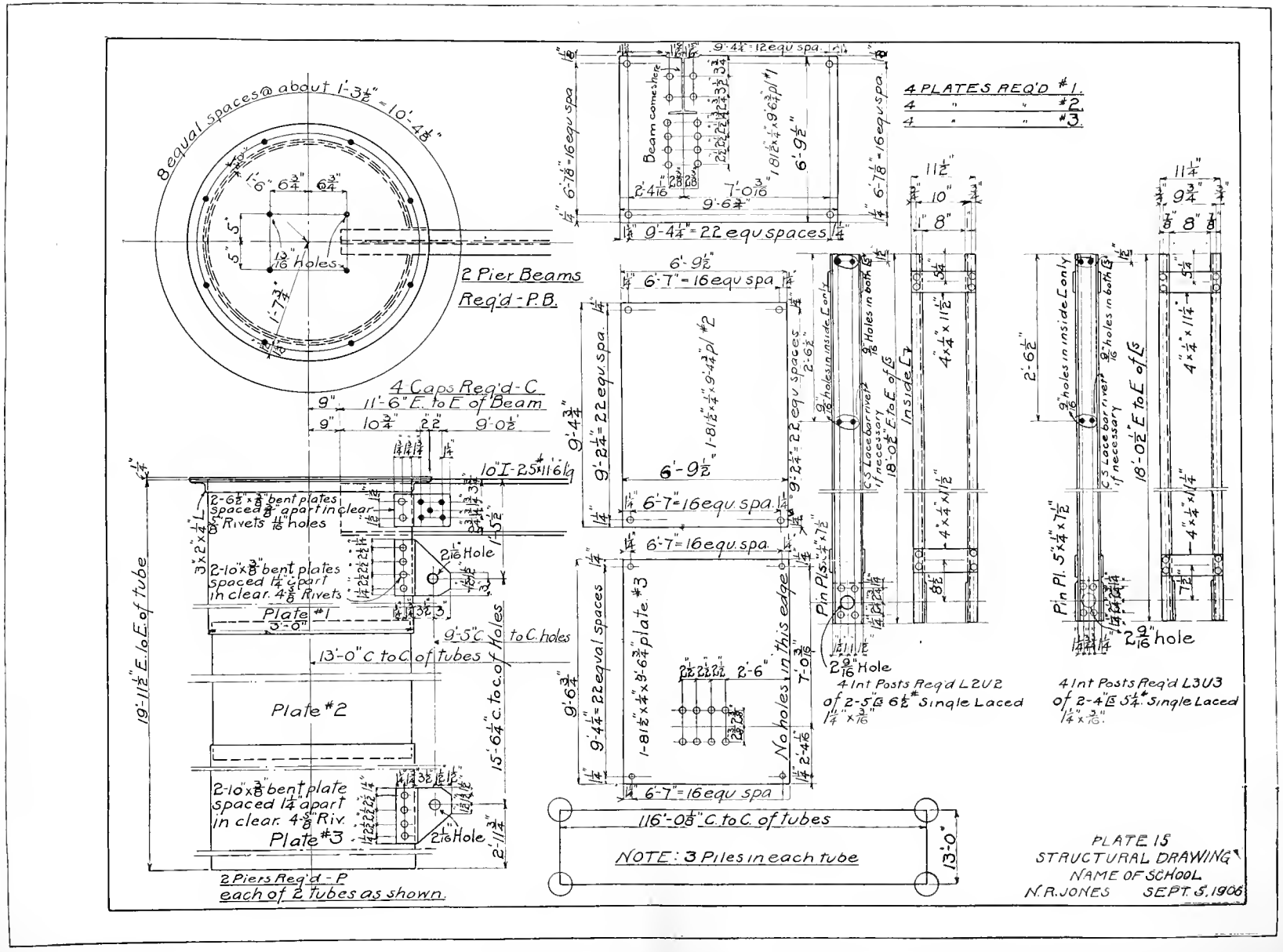
PLATE 15

This sheet shows some of the details and tubes used for the foundations of a highway bridge, also the diagram of the four corners of the piers.

The scale of the tubes is 1" = 1 ft. but the posts are drawn, $\frac{1}{4}$ = 1 ft.

The center of the top view of the tube is 3" from each border line.

The location of the objects can be found by the general rule given on page 28


8 equal spaces @ about 1'-3½" = 10'-4⅝"
2 Pier Beams Req'd - P.B.
4 Caps Req'd - C
11'-6" E. to E of Beam
10"I-25.4# 11'6" lg
2-6½"x⅜" bent plates spaced ⅜" apart in clear. 6-⅞" Rivets 1¼" holes
3"x2"x¼" L
2-10"x⅜" bent plates spaced 1¼" apart in clear. 4-⅞" Rivets
Plate #1
2-10"x⅜" bent plate spaced 1¼" apart in clear. 4-⅞" Riv.
Plate #3
Plate #2
19'-11½" E. to E. of tube
13'-0" C to C of Tubes
9'-5" C to C holes
15'-6¼" c. to c. of Holes
2 Piers Req'd - P each of 2 tubes as shown.
4 PLATES REQ'D #1
4 " " #2
4 " " #3
9'-4½" = 12 equ spa.
9'-4½" = 22 equ spaces
6'-9½"
6'-7" = 16 equ spa.
9'-4¾"
9'-2¼" = 22 equ spaces
9'-6¾"
Beam comes here
Pin Pl. 5"x¼"x7½"
2 9/16" Hole
4 Int Posts Req'd L2U2 of 2-5"x6½"x⅜" Single Laced
4 Int Posts Req'd L3U3 of 2-4"x5¼"x⅜" Single Laced
2'-6½"
18'-0½" E to E of L's
4"x4"x11½"
4"x¼"x11¼"
No holes in this edge
116'-0⅝" C to C of tubes
NOTE: 3 Piles in each tube
13'-0"
PLATE 15
STRUCTURAL DRAWING
NAME OF SCHOOL
N.R. JONES SEPT. 5, 1906

JAN 20 1908

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